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THE

BOOK OF NATURE:

An Elementary Introduction

TO

THE SCIENCES OF PHYSICS, ASTRONOMY, CHEMISTRY, MINERALOGY, GEOLOGY, BOTANY, ZOOLOGY, AND PHYSIOLOGY.

BY

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THIRD EDITION,

TRANSLATED FROM THE SIXTH GERMAN EDITION

BY

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DIRECTOR OF THE MARLBOROUGH STREET LABORATORY AND SCHOOL OF PRACTICAL CHEMISTRY, LECTURER ON CHEMISTRY AND NATURAL PHILOSOPHY AT THE BRIGHTON COLLEGE, AND FORMERLY SENIOR ASSISTANT IN THE ROYAL COLLEGE OF CHEMISTRY, LONDON.

ILLUSTRATED BY NUMEROUS ENGRAVINGS ON WOOD.

LONDON AND GLASGOW:

RICHARD GRIFFIN AND COMPANY.

1855.

PREFACE.

In the present rapidly advancing state of society, the study of the Natural and Physical Sciences has become an essential branch of a liberal education. The advantage of such pursuits is universal; for all men are partakers of the bounties of Nature, and all should possess some knowledge of the manifold operations on which their own enjoyments, and even their existence, depend.

Enlarged views of Nature are more especially requisite for those who watch over the progress of mental development, and whose object and duty it is to direct the tendencies of the progressive spirit of the age, and to counteract the evils of prejudiced and illiberal views either of Natural or of Moral Phenomena. Hence the Artist and the Philosopher, the Poet and the Divine, need a deep insight into Nature, and an enlarged apprehension of her economy and her laws. The Manufacturer, the Husbandman, and the Merchant, whose avocations may be prosecuted with the aid of a knowledge of those branches of Natural and Physical Science which are indispensable to their special pursuits, are likely to be more uniformly successful when acting upon principles derived from a thorough comprehension of the relation of Nature's laws to one another.

It may hence be inferred that the Natural and Physical Sciences are of the highest importance to all classes of the community, and that they ought to form an especial branch of study in every institution devoted to the instruction of youth.

The Author's object has been to render the Book of Nature a Manual that may be appropriately placed in the hands of pupils in all educational institutions where the importance of a general knowledge of the Natural and Physical Sciences is recognised. Founded on a scientific basis, and composed with simplicity and clearness, it presents a general and comprehensive view of all the principal branches of the Natural and Physical Sciences.

PREFACE.

The composition of the various sections by the same author is intended to secure the advantage of a uniformity of style and treatment; to avoid the repetition of numerous general statements; to exclude all varying and contradictory views; and, finally, to avoid all inadequate explanations and expressions, which so greatly retard the progress of the student in the perusal of scanty outlines of the several sciences composed by different authors.

The estimation in which the BOOK OF NATURE is held by the Germans, who have justly been styled a "Nation of Thinkers," is testified by the sale of upwards of twenty thousand copies in the short space of five years, and by the high encomiums of some of the most eminent Professors of the individual branches of science on which it treats.

The work has received many new illustrations, some of them original, and others copied from Regnault's *Cours Elémentaire de Chimie*, and from the *Cours Elémentaire d'Histoire Naturelle*, par MM. Milne-Edwards, A. de Jussieu et Beudant, which were placed at my disposal by the Publishers, and which have enhanced its beauty and usefulness.

H. MEDLOCK.

Royal College of Chemistry, London,
October 1851.

PREFACE TO THE SECOND EDITION.

In preparing the Second Edition of the Book of Nature, I have incorporated the additions and improvements introduced by the Author into the Sixth German Edition which has been recently issued from the Press.

In the section on Physics a more convenient arrangement has been adopted; and a new chapter on the Mechanism of the Clock and of the Flour-mill added.

The section on Astronomy has been almost entirely re-written, and rendered more uniform in language and style of treatment with the rest of the work.

The section devoted to Chemistry is considerably extended; and a new chapter on Organic Radicals introduced.

In revising the proof-sheets, and making the copious Index, I have received the valuable assistance of my friends Dr. Philip W. Hofmann and Mr. Charles Harwood Clarke, to whom my best thanks are especially due.

H. MEDLOCK.

20 *Great Marlborough Street,*
March 1853.

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INTRODUCTION.

THE BOOK OF NATURE has, for thousands of years, been displayed to the gaze, the admiration, and the delight of mankind. In great and glorious characters, it testifies to the wonderful power and goodness of its Divine Author:—even the meanest or the uncomeliest thing in existence declares the infinite wisdom of its Creator.

In all times and in all places man has sought to understand the language of Nature; and thousands have applied themselves to its study with perseverance, energy, and profound attention. The exertions of the most intellectual and ingenious of men have been exercised in rendering the contents of this great volume intelligible and accessible to those who seek in its wonderful page for instruction and wisdom.

These labours, however, have not been crowned with complete success: there are in this Book still many marks and signs, even whole pages, which we do not understand, which appear so doubtful or obscure, that we can only guess at their meaning, or conjecture what may be their connexion with other portions of the same perfect work.

But as it is only after we have deciphered the separate characters that we discover the meaning of an ancient inscription, so we progressively advance from the knowledge of individual facts and simple objects, to the recognition and comprehension of the general laws of Nature on which they depend.

The efforts of the earlier students of Nature were solitary, interrupted, and uncombined, and therefore they led to no important results. A subject so full of marvel and mystery can only be successfully prosecuted when men are in the possession of leisure, and when they enjoy the blessings of peace. But these circumstances we rarely find to have been the lot of the learned and the wise, the distinguished men of ancient times. In the history of the earlier nations and empires we learn that the few who directed the destinies of the people at large, were so much occupied either in acquiring or in adjusting political power, that only a limited number of favoured individuals, here and there, had leisure to cast a few hasty glances on Nature.

People were then fully engaged in providing for their mere physical wants; civil order had to be established, and life and property to be secured. When wars and other calamities left them a breathing-time, this was chiefly and necessarily spent in the performance of their legislative and religious functions.

Hence the sciences cultivated in the more ancient times, were those of civil polity, law, and religion; and to all these, but especially to the last, the fine arts were more conducive than natural science, and were consequently more successfully cultivated.

Our sketch of the progress of science is divided into that of the earliest, the middle, the modern, and the present age.

EARLIEST AGES.

The ancients were content to use and to enjoy the gifts of Nature, but had little desire to know their causes or their effects. They had everything to learn. Their usual employments were hunting and fishing, and to these were subsequently added the tending of cattle and the tillage of the soil—occupations which supplied food and clothing, the prime necessaries of life. Hence, in consequence of their daily intercourse with Nature, they noticed many facts and phenomena which, individually and collectively, were useful to their successors.

The Chinese and the Egyptians, who, even at this early period, had formed themselves into well-organized communities, are the earliest nations among which we meet with a large amount of artistic knowledge, as well as regulations which evince that they enjoyed an intimate intercourse with Nature. Yet both of these nations had only attained to intelligence of some individual words or passages of this Book; but to an understanding of its spirit and unity, or even to an intelligent apprehension of its less obscure chapters and pages, they never reached.

MIDDLE AGES.

The Greeks, the most civilized people of antiquity, were surrounded by the bounties of Nature, which almost spontaneously yielded up to them all the necessaries of life. And thus, not being compelled to wrest from Nature her treasures by incessant labour and patient attention, they entered less deeply into her mysteries than might have been anticipated. It was the spirit of Nature collectively, and of the human mind specially, that formed the main

objects of their observation and reflection; and thus the intellectual, moral, and political sciences were more successfully cultivated than those of Nature.

The powerful people of Rome desired only conquest and dominion; their principal occupations were war and legislation; they had no inclination for science, which never thrives unless embraced with love, and nursed in the lap of peace. This nation, which made all kingdoms tributary to itself, never dived into the kingdom of Nature; and whilst it prescribed laws to all people, it had no idea of the eternal, immutable laws of Nature which overrule the transitory laws of men.

After the overthrow of the great Roman Empire, a stormy period succeeded. Prodigious swarms of turbulent people forsook their rugged homes, in quest of new and more congenial habitations. These brought war and desolation in their train. like a destructive flood, they destroyed everything which lay in their track. Art and science bade farewell to Europe, and sought and found an asylum in the more peaceful countries of Asia. While Europe was torn to pieces by savage wars, science was cultivated and expanded in Arabia, and much valuable knowledge was brought thence by the Crusaders.

MODERN AGES.

Both the external and internal circumstances of Europe became gradually more favourable to the promotion of science. The Christian faith, strengthened and cemented by the testimony and the blood of martyrs, united the nations in defence of their country and common religion, assailed by the irruptions of foreign barbarians. The Empire of Germany, founded on the ruins, and composed of the relics of Roman power and civilization, grew up into a permanent and powerful refuge for art and science. Wars and warlike expeditions were still frequent, yet in the seclusion of the monastic establishments, and within the walls of strong, fortified cities, science and art, trade and manufactures, found a safe abode, and were cultivated with energy and success. As men were connected by the bond of proximity and interest, their wants multiplied as their means of supplying them were increased, and the effects of combination and concentration were a more abundant supply of the treasures of Nature. There were, besides, other causes co-operating in the ampler diffusion of natural science. The discovery of printing afforded the facility of preserving and transmitting every invention, experiment, and observation, and the discovery of America not only displayed to the wondering inhabitants of Europe a multitude of curious and remarkable objects, which not merely excited their curiosity, but enkindled the passionate desire of more extensive discovery and more accurate examination. In England, Scotland, Italy, France, and Germany, they founded Universities, establishments in which all the sciences were sedulously cultivated by the most distinguished scholars of that age. The connexion of medical and physical science was especially favourable to the promotion of the latter, which, from the earliest ages, has been considered as the sure foundation of medical knowledge and practice.

PRESENT AGE.

Armed with the experience of the past, and favoured by a lengthened duration of peace, the present age is more distinguished for scientific pursuits

than any former period of the world's history. The more important nations of Europe, during the greater part of half a century, have sheathed their swords, so long drawn against themselves; and England, France, and Germany no longer emulate each other in the bloody works of destruction, but strive for the mastery in science, arts, and manufactures.

Many of the most eminent and ingenious men have applied themselves exclusively to the study of Nature. They were endowed with a keen perception of the essential importance of the physical sciences in philosophy, medicine, agriculture, arboriculture, and manufactures. Under a combination of favourable circumstances and of associated efforts, science has lately made gigantic progress.

In Germany, the General Association of Naturalists was first established, and every year they meet to excite and encourage each other in their labours, to extend the empire of science and the love and knowledge of Nature. The British Association for the Encouragement of Science meets annually for similar purposes. From neighbouring nations, and even from the most distant parts of the world, there is a continual intercourse or scientific commerce carried on, which has a direct tendency to awaken the energies of men, as well as to enlarge their knowledge and excite their curiosity.

The science of the present day has no mysterious secrets which she carefully or churlishly conceals, freely and generously bubble unceasingly her fountains for every one who approaches her with the noble thirst of knowledge.

Happy youths of the present age, whose cradle was rocked under the shadow of the peaceful olive, take advantage of the favourable circumstances of the times, and acquaint yourselves with Nature! For, as the man who learned a new language was believed by the ancients to become possessed of a new soul, so man acquires a new sense with the acquisition of every new branch of natural science.

"*Thus Nature addresses herself to the recognised, the misused, and unknown senses; thus, by thousands of phenomena, she speaks with herself and to us; to the attentive listener she is nowhere dead, never silent.*"

With these words of GOETHE, we recommend to your acceptance and study THE BOOK OF NATURE.

1.

By the term Nature we understand the tenor or the united totality of all that can be perceived by the senses.

We *feel* that which is in immediate contact with our own bodies; we *see* whatever is presented to the eye, whether at a greater or a less distance; we *hear* the varieties of sound around us; we *smell* the fragrance of the flowers; and we *taste* the peculiar savours of different things.

Our senses are therefore the essential media between mind and Nature. They alone give information to the mind of the presence of that which is external to it; so that it is only through the senses that the mind has any conviction of an external world.

It is impossible for the mind to form a conception of any one part of Nature, unless it be perceptible to the senses. The blind, by the sense of touch, can, it is true, form a conception of the shape of an object, but they cannot form the least idea of the different colours; and it is impossible to convey any notion of this by mere description. Blue and red can no more be described than can a sound or a taste.

Consequently, if the mind wishes to become acquainted with Nature, it must employ the senses as principal guides; it must despatch these its servants into the unknown domains of Nature, and form its conceptions and ideas in conformity with the information obtained through the means of the senses. Futile will be the endeavours of the most ingenious mind, which attempts to investigate or expound Nature either as a whole or in individual parts, on purely reflective or logical principles. We must refer constantly to the evidence of our senses: for the history of scientific progress clearly proves that those who have neglected or despised the guidance of their senses, and who would comprehend Nature on purely intellectual principles, have been led farthest astray.

2.

Though we justly attach a high importance to the perception of the senses in the investigation of Nature, it is not by itself adequate to the attainment of this knowledge. The child and the imbecile, as well as the savage, are susceptible of impressions, yet they make no advancement in the knowledge of Nature, for they are not in possession of a correspondingly developed understanding, which alone is capable of rightly apprehending and judging, of arranging and comparing, the facts communicated through the medium of the senses. The mind alone is able to combine the different observations, and thus, conducted by the senses, to obtain a deeper insight into Nature.

The attentive consideration of Nature we call *observation*, and to observe with the view of understanding is called *investigation*. When we ourselves perform certain operations, or fulfil certain conditions, in order to observe an appearance more accurately, or so that we may be able to repeat or continue the operation, this action is called an *investigation* or *experiment*.

3.

All appearances or perceptions do not make an equal impression on our senses. That which is perceptible at once, both to sight and to feeling, is

called an Object. Thus, Stones, Plants, and Animals, are Objects. That we are justified in classing with objects the atmosphere and the heavenly bodies, will only become perfectly clear on a closer acquaintance with Nature.

On the other hand, we name *Phenomena* all such appearances as are of themselves and at the same time perceptible or revealed to us by only one of our senses. Thus, heat is apprehended only by the feeling, light by the eye, sound by the ear; hence heat, light, and sound are designated by the term *Natural Phenomena.*

Certain perceptions, such as those of the colour, the smell, and the taste of many bodies, are usually called *Properties*.

Objects occupy *Space*, and can be measured and compared; phenomena fill up a portion of *Time*, and divide it by their succession, and repetition

Nature is therefore revealed in objects and phenomena.

4.

If we attentively consider an object, we are sensible that it does not always present the same appearance. Certain changes are easily perceptible. Sometimes it changes its place, sometimes its figure, sometimes its colour; in a word, every object is to be seen under a greater or less striking variety of accidents or aspects.

What is the origin or foundation of these appearances,—whence arise these mutations to which objects are constantly subject?

We will endeavour to answer this question by an example.

There lies a stone on the ground. Suppose we lay hold of it and lift it up

The stone by this action evidently changes its position, and we perceive that a motion is communicated to it. The stone is the *Object*, and the motion is the *Phenomenon.*

What now was the ground or the cause of this phenomenon of motion?

Nobody will, in this case, doubt that it was the will, the individual act, which by the laying hold of, and the lifting up of the stone, communicated the motion, and caused the change of place.

But what happens if we now leave the elevated stone to itself, by opening and withdrawing the hand? Does the stone retain the same position?

By no means, it remains neither suspended nor hovering in the air, but the moment we withdraw the hand it falls to the ground.

Moreover, we have here again a phenomenon of motion which is certainly independent of our will. For if, at the very instant the stone is relinquished, we express the most decided desire for its remaining where we leave it, it will fall to the ground notwithstanding.

It is indifferent, as experience proves, to what height we may lift up the stone, under similar conditions, all objects will manifest the same phenomenon.

There must necessarily be a cause present, which produces in the most dissimilar objects the same phenomenon of falling—a cause altogether independent of human volition—a cause which is invisibly united to every object, and belongs to its existence

Such a cause of a phenomenon independent of human will, we call a *Force*, or *Natural Force.* For example, the power which we consider as the cause of the falling of bodies, is called *Attraction*, or the *Force of Gravitation.*

As Nature exhibits a great number of very different phenomena, it might easily be supposed that many different forces are constantly active in producing these different results.

This, however, is not the case. Attentive observation has proved that a single force is adequate to the production of a multitude of different phenomena. It is probable that, taken on the whole, there are only a few final causes or forces in existence, whereby all the phenomena surrounding us are occasioned.

In the observation of Nature, we have therefore, in the first place, to comprehend *Objects*, and the *Phenomena* which they manifest. We have then to account for the *Causes* or the *Forces* which produce these phenomena. The complete account of this scientific knowledge we call the *Knowledge of Nature*, or *Natural Science*.

5.

Let us now behold Nature.

The most suitable means of attaining this end will be to take a walk, and consider well whatever presents itself to our senses. We directly perceive many and very various objects. The fields and commons are covered with plants and grass; the distant hills are crowned with broom, or woods, or forests. In the vale at their feet the sparkling brook glides along, while in the atmosphere the clouds chase each other in rapid succession. Complete rest and stillness are nowhere to be seen. Leaves rustle, branches wave, the flowing water eddies and ripples everywhere we meet with the most varied forms of animal life in incessant impulsive activity. What a multitude of objects! what a multiplicity of phenomena! Where shall we commence our research? How shall we comprehend the individual object in the constantly moving panorama of Nature?

Indeed the multitude distracts us; we feel discouraged in our efforts to obtain a right apprehension of what we behold, we return home little instructed by our walk.

But even here, within our four walls, how manifold and multiform are the objects capable of arresting our attention! The warmth radiating from the grate, the disappearance of the wood consumed by the fire, the hissing and bubbling of the water boiling in the tea-urn—all these are phenomena which claim our observation. What remarkable properties are exhibited by the glass furnishings of the room! Whilst the window panes permit unaltered the appearance of external objects, our spectacles increase their apparent magnitude, and the mirror presents a faithful likeness of ourselves.

These are, in truth, things which we daily see, and with which every one is acquainted; but if we inquire into the proximate causes of such phenomena we perceive that it is not easy to extemporize a satisfactory solution.

Thus with the materials and objects of investigation, we are always and everywhere supplied. It is only requisite now to show how to proceed to attain a comprehension, and to survey Nature in her multiform aspects and manifold phenomena. To study all at once would be impossible. With this view, we adopt a systematic treatment of the various subjects, making the sciences follow one another in a natural sequence.

6.

Thus then we are under the necessity of *subdividing* the natural sciences. It is not possible to do this with absolute precision; for though certain natural divisions readily present themselves, yet in the richness of Nature every subject is always more or less intimately connected with every other.

It is, moreover, difficult to afford a systematic view of the whole Natural Sciences to one who is totally unacquainted with their details, or who only knows them superficially; for a clear comprehension of the whole can only be attained by him who knows precisely its constituent parts. If, notwithstanding, we make an effort to divide the great kingdom of Nature into different provinces, it is chiefly with the view to point out the course by which we mean to pursue our journey through it.

We have already shown that Nature is revealed partly in *Objects*, and partly in *Phenomena;* and hence the entire science separates itself into two primary divisions—the science of objects and the science of phenomena.

7.

The Science of OBJECTS, which is commonly termed NATURAL HISTORY, is divided into three parts or divisions. The principles on which this division is founded will be most easily rendered intelligible by examples.

From the thousands of objects with which we are surrounded, we choose a piece of Sandstone, Chalk, or Granite; and pieces of Sulphur, Coal, common Potter's clay, white Pipe-clay, and yellow Tripoli.

These objects are certainly very different from one another, yet they present this property in common, that every one of them is homogeneous (similar) in its whole mass. If we break off a fragment from the piece of Sandstone, or Chalk, or Coal, we have in this bit, the same Sandstone, the same Coal, the same Chalk, only of smaller size. We can thence convey to any one as accurate a knowledge of the essential qualities of one of these bodies, by presenting him with a small piece, as if we showed him an entire mountain of it.

In none of these objects do we perceive any individual portion which exhibits an essential difference from the other portions. We cannot infer that any one portion is more necessary to the existence of a piece of sandstone than is any other, or that the one particle has a different function or another destination than the other. The minutest atom of chalk adhering to the finger, is as perfect a bit of chalk, as the mass of this substance which constitutes the stratum of a mountain.

Even the Granite, which appears, indeed, to be a composition of different materials, forms an exception rather in appearance than in reality, for on the whole it is homogeneous. As will be shown in a subsequent part Granite is a uniform mixture of Quartz, Mica, and Felspar, and it is indifferent whether it be only of the size of a cherry-stone, or of as ample dimensions as the huge Granite-block which supports the equestrian statue of Peter the Great, or of the still greater mass that forms the peaked mountain of Goatfell, in Arran. All are equally perfect pieces of Granite.

Thus, therefore, there are objects which are homogeneous in their mass, and in

which no parts specially formed for special purposes can be distinguished. These are termed MINERALS, *and that branch of natural science which treats of them is called* MINERALOGY.

The case is altogether different if we submit to consideration a tree, or a shrub, or even a flower, a leaf, or a root.

How different are here the individual parts in *form*, *colour*, and *density!* It is easy to be observed that the peculiarly formed parts of a tree have special functions and destinations; for suppose it to be deprived of its root, its bark, or its leaves, we soon are sensible that it is going rapidly to decay. From a part of a tree we can form no adequate conception of it as a whole, when the whole is previously unknown to us.

But still more remarkable is that which, by the help of the microscope, we are able to see in the interior of the root, the bark, and the leaves of a tree. We perceive the sap it contains is in motion, ascending and descending, the liquids in it evaporating or being assimilated. On the outside of the tree, shrub, or herb, we are not sensible of any motion communicated from within, or occasioned by itself. It is true that the wind shakes the branches and top of the oak, but of itself, not even a single leaflet is in a condition to move. The wind and the forester scatter its seeds over the ground, but the stem remains immoveably fixed where it first took root in the soil.

Objects with parts specially adapted for certain functional purposes, without voluntary external movements, are termed PLANTS, *and the science which treats of them*, BOTANY.

There is still another group of objects which coincide with plants in being provided with peculiarly constructed parts, to which special functions are assigned, and in possessing an internal movement, but which are, nevertheless, not plants.

They are distinguished from plants by their capability of voluntary external movements, whereby they can not only change the posture and attitude of their individual parts, but they can move from one place to another.

Objects endowed with specially formed parts, adapted for the fulfilling of certain functions, and are besides capable of voluntary external motion, are called ANIMALS, *and the science which treats of them is called* ZOOLOGY.

All objects, consequently, are either similar or homogeneous, like minerals, or they are dissimilar or heterogeneous, like plants and animals. The latter have peculiarly constructed parts, adapted for certain functional purposes; these parts are termed *Organs*. The united activity of all the organs of a plant or an animal, we call *Life*, and hence plants and animals are designated *animate* objects, while minerals are called *inanimate* objects.

8.

The Science of PHENOMENA, which is sometimes termed PHYSICS, or NATURAL PHILOSOPHY, is also divisible into three parts.

We are taught by observation, that all natural phenomena form three primary groups or divisions, each one distinguished by peculiar characteristics. These we will now render comprehensible by examples:

If we strike a bell with a hammer, we hear a sound. The same will take

place on the drawing of a bow across tightened strings. A lens of polished glass apparently enlarges the magnitude of every object viewed through it: with the same lens we can intercept and concentrate the sun's rays into a focus or point, and thereby kindle any combustible object; in every body elevated above the surface of the earth and then relinquished, we observe the phenomenon of falling; by the drawn bowstring we can communicate a swift motion to the arrow; the water which we heat is changed into steam; and when the steam is cooled, it again becomes water.

Thus we produce very different phenomena,—*sound, magnifying effect, combustion, falling, motion,* and the *formation of steam.*

Though these phenomena differ greatly, they have still something in common: all objects in which they are made to appear, or by which they are produced, undergo no essential change in consequence.

The sounding bell and the string, the burning glass, the falling stone, and the bow-string, all remain unchanged. Even the water, which has been converted into steam, resumes its original condition whenever the temperature is reduced sufficiently to admit of another change, without its suffering the least alteration of its essential qualities.

The heavenly bodies and their motions are also phenomena for our present consideration: accompanied as they are by no perceptible change, they are arranged among the above-mentioned phenomena.

Phenomena without essential change of the objects contributing thereto are termed PHYSICAL PHENOMENA, *and the science which treats of these is called* PHYSICS, or NATURAL PHILOSOPHY.

The case, however, is totally different with another series of phenomena which we have next to consider.

When we burn a piece of coal, of wood, or of sulphur; the coal, the wood, and the sulphur, entirely disappear. They pass into another condition, having entirely lost their former properties. When sand and potash are mixed together and exposed to strong and continued heat, both bodies melt together and become *glass;* in which new combination the original materials cannot be perceived. Still more striking is it when sulphur and mercury are heated together. Both substances entirely disappear, and instead of the yellow sulphur and the shining silvery mercury, we obtain the beautiful red vermilion. Of similar examples, thousands could be given, wherein the objects which we select for the production of such phenomena experience an essential change, and in their place objects appear with totally different qualities.

Phenomena accompanied with essential change of the objects applied thereto are called CHEMICAL PHENOMENA, *and the science which treats of them,* CHEMISTRY.

Finally, we have remaining a third group of peculiar phenomena, called vital phenomena, because they only appear in animate objects, viz., in plants and animals. These are, for example, their growth, the motion of the different fluids in their interior parts, the reception and appropriation of the nourishing media, &c.

The phenomena of animated objects are called PHYSIOLOGICAL PHENOMENA, *and the science which treats of them,* PHYSIOLOGY.

TABULAR VIEW of the foregoing Divisions of the entire subject of Natural Science.

A—SCIENCE OF PHENOMENA.			B—SCIENCE OF OBJECTS.		
1.	2.	3.	4.	5.	6.
Without change in the objects,	With change in the objects,	In animated objects,	Which are homogeneous in their mass,	Which are heterogeneous in mass, and without voluntary motion,	Which are heterogeneous in mass, and endowed with voluntary motion,
PHYSICS.	CHEMISTRY.	PHYSIOLOGY.	MINERALOGY.	BOTANY.	ZOOLOGY.

9.

The sequence or order in which these different branches of natural science are to be pursued is not a matter of indifference. For such as are of riper years and experience, the most advantageous course is, in the first place, to acquire a knowledge of general phenomena and their laws, which are almost incessantly repeated by nearly every object. It is easier and more agreeable to the developed understanding to survey, in the first place, the great outlines and general principles, rather than labour at the comprehension of many dissimilar individual forms. In this case the most suitable plan of study is to begin with *Physics* and *Astronomy*, to be succeeded by *Chemistry* and *Mineralogy* as their indispensable complement. These four sciences contain the fundamental knowledge necessary to the thorough comprehension of animal and vegetable life. Then follow *Botany* and *Zoology*, of which *Physiology* is generally reckoned a branch; unless it be intended to handle that subject more profoundly and with higher scientific aims.

This is the arrangement adopted in THE BOOK OF NATURE, with the express intention of making every earlier division more or less introductory to that which follows.

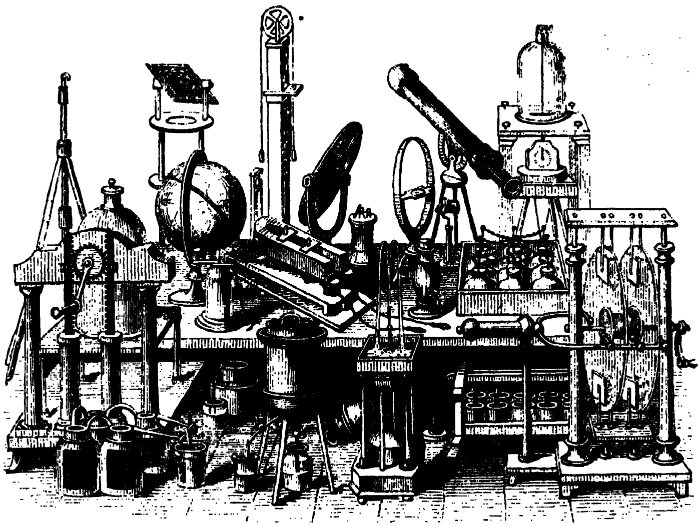
Another course must, however, be followed, if it be wished to initiate the young into the knowledge of Nature. The child more easily comprehends the relations of external forms, the magnitude of objects, their qualities, and other characteristics, than he does the forces and the laws whereby phenomena are regulated. On these branches it is difficult for a child to acquire just notions, or even clear conceptions.

With children, we may first begin to direct their attention to the animal kingdom; and of all animals insects offer the richest and most interesting materials, which may everywhere and at all seasons be obtained in the living state. When they become more expert in observing and comprehending, with advancing age and frequent practice, they may be introduced through the vegetable to the mineral kingdom.

The study of physics and chemistry cannot usually be undertaken with advantage earlier than the age of fifteen.

In fine, a repeated survey will complete the whole picture of Nature, and make it appear in that intimate connexion which we ought not materially to derange. But every teacher may choose his own way, if he be only able to walk securely himself, to awaken the desire for the study, and to preserve the zeal of his pupils.

All ways, then, tend to the same end, but he who would reach the end must not avoid the way.



PHYSICS.

"Thou hast ordered all things in measure and number and weight, for Thou canst shew Thy great strength at all times when Thou wilt, and who may withstand the power of Thine arm?"—*Wisdom of Solomon*, xi. 20, 21.

1. PHYSICS is that branch of Natural Science which treats of such phenomena as are unaccompanied by any *important changes* in the objects in which the phenomena are observed, or which serve for their production.

Such phenomena as these are—the falling of a stone, the sounding of a bell, or the magnifying effect of spectacles, as the objects by which they are produced undergo no change. As little do the rays of light affect a window-pane as they pass through it, and even heat produces only a temporary change in the condition of bodies.

In distinguishing physical phenomena an apparent difficulty can only arise when they occur simultaneously with other phenomena.

The heat disengaged in the combustion of coal belongs to the physical class of phenomena, while the *metamorphosis* which the coal undergoes must be classed under the head of *chemical* phenomena.

2. Man, from his earliest age, by observation, by the eye, the sense of touch, and still more distinctly by the motion of his body from one place to another, arrives at a conception of the relative position of surrounding objects, or, in other words, at the idea of *magnitude* or *form*.

It is not the sense of vision alone that endows him with this conception. A

young child as often grasps at distant objects, at the moon for instance, as it does at those within its reach. A person born blind, who acquires his sense of vision by operation only, in after years, is unable at first to judge by the eye either of distance or of magnitude. All objects appear to him equally distant, and he is incapable of judging of their size. It is only by moving about and feeling the objects which are visible, that he is enabled to distinguish between vicinity and distance, or to recognise a difference in size. It is to the habit of observing from our early youth with both senses, that we are indebted for our ability of judging correctly, with the eye alone, of magnitude and distance.

Experience also teaches us that magnitude may be followed out in three directions, which we distinguish by the terms *Length*, *Breadth*, and *Depth*.

That which is conceived as extending in three directions is *Space*. As we can imagine either of these three directions to be carried out *ad infinitum*, we may likewise define space as the infinite universe surrounding us. It is, however, much more easy for us to form a conception of any limited space than of the illimitable expanse of Heaven.

3 In like manner every man is endowed unconsciously with a conception of *Number*, by the variety and the repetition of the objects surrounding him, and with an idea of *Time*, by the succession of phenomena or even by the mere train of his own thoughts Certain points of departure, as well as an acquired practice, are essential to the formation of a judgment of time and number, without them we should be as little capable of forming accurate conceptions of these subjects as we should of space. The act of breathing, the beating of the pulse, the alternations of day and night, and of the seasons, are the kind of phenomena that aid us in measuring and dividing time.

Space, Number, and Time, are, therefore, the generalities which force themselves upon our minds by every observation, and are of special importance in the study of most natural phenomena. The more accurate observation of space and number forms the subject of a special science, which is called *Mathematics*.

4. That which fills space is *Matter*. If all space were filled with matter, the latter, like the former, would be infinite, and space and matter would, therefore, be the same. But this is not the case Matter exists only in certain portions of space, and is always limited in extent. Matter, as a limited, finite substance, is termed *Body* or *Object*.

The celestial bodies, as well as the earth, are such limited portions of matter, or bodies, existing in space. Their dimension is extremely small when compared with that of space

5. If we examine matter in the various forms in which it has yet been defined, we can perceive no reason for its undergoing any change As matter, it should ever be alike, and remain in the same state, and the same place. It would, therefore, be perfectly unchangeable, fixed and motionless, and would not attract and occupy our attention by the change in the phenomena observable in connexion with it Such a condition of matter we express by the term *vis inertia*. Every phenomenon, therefore, is produced by the overcoming of this inertia by some particular cause.

Hence we must assume that in addition to matter, there exists a special cause of the phenomena which are exhibited, a cause which is termed *Force*. Two ideas may be formed of the relation between force and matter. We may either

consider force to be independent of matter, separable from it, and influencing it, perhaps, in the manner in which we conceive that the Deity influences the universe as its Creator and Ruler, or force may be considered as being inseparable from matter, as is the body and soul in the living being.

Such general views are, however, the more indistinct and indefinite the less we know of the facts upon which they must be grounded. It is, therefore, advisable to become first thoroughly acquainted with individual natural phenomena, and afterwards to endeavour to form more general views, and to denote them by suitable expressions.

General Properties of Matter.

6 The following are the general properties of bodies: 1. *Magnitude and Form*, 2. *Impenetrability;* 3. *Inertia;* 4. *Divisibility*, 5. *Porosity*, 6. *Compressibility*, 7. *Elasticity*, 8. *Expansibility.*

Observation teaches us that the above mentioned properties are possessed by every substance, without exception, whilst of the numerous distinctive marks which we perceive in every individual object, the greater part of them are observed only in particular objects, and are, therefore, called *special* properties, as for example colour, form, &c.

7. As matter occupies a certain portion of space, it must be possessed of *magnitude*, and in describing physical phenomena, we have so frequently to refer to it, that it appears to us desirable to point out here the means of arriving at a correct idea of magnitude, or, in other words, of measuring it.

If we follow magnitude only in one unchangeable direction, as a straight line, the means of determining it is called a *measure of length.* It will be readily seen that it is of the greatest importance for scientific observation, as well as for commerce, to possess a universal, unchangeable measure of length, and it is particularly important to determine the unit of the measure of length in such a manner, that in the event of its being lost or falsified, it can easily be again found.

Several scientific men in France were commissioned to discover a unit of length After having most accurately measured the fourth-part of the largest circle passing through the poles of the earth (the meridian), and divided it into ten millions of equal parts, they adopted one such part as a measure of length and called it a *meter.* The length of the meter is 39·37079 English inches.

The meter is divided into smaller parts according to the following plan —

Meter, M		Decimeter, Dm		Centimeter, Cm		Millimeter, Mm
1	=	10	=	100	=	1000
		1	=	10	=	100
				1	=	10

Here, therefore, the millimeter is the smallest measure, and having been once determined, it may be conveniently employed for the comparison of other measures It is equal to very nearly $\frac{1}{25}$ English inch.

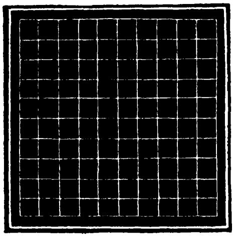
In most other countries the unit of measure is the foot which is divided into ten or twelve inches. In England the imperial yard of 36 inches, or three feet, is the legal standard of length.

The inch is divided into ten or twelve parts, which are called lines:—

Comparison of Measures of different Countries.

	Foot.		Inches.		Lines.		Millimeters.
England - - - - - - - -	1	=	12	=	144	=	304
Prussia (Rhenish foot) - - -	1	=	12	=	144	=	313
Parisian or old French foot - -	1	=	12	=	144	=	324
Austria - - - - - - - -	1	=	12	=	144	=	316
Hesse Darmstadt - - - - -	1	=	10	=	100	=	250
Saxony - - - - - - - -	1	=	12	=	144	=	283
Frankfort-on-the-Maine - - -	1	=	12	=	144	=	284
Brunswick - - - - - - -	1	=	12	=	144	=	285
Wurtemburg and Hamburg - -	1	=	10	=	100	=	286
Electorate of Hesse - - - - -	1	=	12	=	144	=	287
Bavaria - - - - - - - -	1	=	12	=	144	=	291
Hanover - - - - - - - -	1	=	12	=	144	=	292
Baden - - - - - - - -	1	=	10	=	100	=	300

Those measures which are divided into ten equal parts, as the meter, are called *decimal measures*, as fig. 1, which is a square inch divided into ten square lines, and fig. 2, which represents a cubic inch divided into cubic lines.



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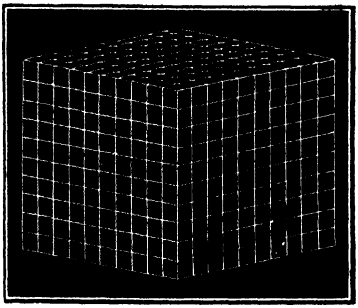


Duodecimal measures, which are most commonly used in this country, are divided into twelve equal parts. A square foot is a plane measuring twelve inches in length and in breadth, whilst a cubic foot measures twelve inches in length, breadth, and depth.

8. The occupation of space by matter is rendered manifest to us by its *impenetrability*. In the same space which the earth occupies there can be no other celestial body at the same time, and daily experience teaches us, that in the space occupied by a mountain, a tree, or by our own bodies, no other material substance can be simultaneously present.

The impediments we should encounter by moving forward in one direction, result from the impenetrability of the substances we meet with in our way.

The *air* likewise occupies space; it is impenetrable, and is, therefore, considered as a body or a portion of matter. This requires a more positive proof. If we immerse an ordinary drinking-glass, with its opening downwards, in water, no water will enter the glass, however deep we may immerse it. This depends upon the *impenetrability* of the air contained in the glass, which does not allow the water to occupy its place. The possibility of descending to a

great depth in the sea, by means of a *diving-bell*, depends partly upon the impenetrability of the air which it contains.

A vessel which, in common language, is called *empty*, is, in reality, not empty, but filled with air; and it is not until this is displaced, that we can introduce another body, for instance, water, into the space which the air previously occupied.

All kinds of matter do not offer an equal resistance to the motion of our bodies, but we perceive, in this respect, a great difference. For example, those objects which we term *solid* are much more difficult to displace than those which are *liquid*: and in the case of *gaesous* bodies we scarcely feel that they oppose a resistance to our movements; they are mobile in the highest degree. Matter, therefore, presents itself in three different states, which are called *states of aggregation*, namely, *solid*, *liquid*, and *gaseous*. These we shall subsequently consider more minutely.

9. It has been shown that matter presents to us various phenomena only when influenced by the forces of nature: when it is uninfluenced by any of these forces, and remains in a state of rest, its condition is called its *inertia*. As this general property of matter is most remarkably displayed by the phenomena of motion, the consideration of it will be discussed more minutely when we treat of motion generally.

10. All substances may be divided into small particles by suitable means. Stones and grains of corn may be ground to fine dust, or flour; metals reduced to small particles by means of files, beaten into thin leaves by the hammer, or drawn into wires finer than hairs. Water contained in a vessel may be easily divided into single drops, and each drop may be spread over a large surface by a brush. The surface thus moistened becomes dry after a short time, owing to the evaporation of the water, which is converted into extremely small particles, no longer perceptible to the eye.

Divisibility is, therefore, a general property of bodies: their division is effected either by the proper implements, in which case they suffer *mechanical* division; or by natural forces, when they are said to undergo *physical* division.

The extent to which division may be carried is best shown by examples. The little line (–) shows the length measure, which is termed a *millimeter*. (See § 7.) The silk-worm spins filaments, 100 of which must be placed side by side to occupy the space of a millimeter (about $\frac{1}{25}$ inch). But metals have been drawn out into wires of such fineness, that one hundred and forty of them have together only the thickness of one silk filament, and twelve hundred of them placed together occupy the space only of one millimeter.

Bodies may, however, be divided to a much greater extent by physical means. If, for instance, a grain of salt be dissolved in a glassful of water, every drop of the solution that can be taken up on the point of a needle contains a particle of the salt.

However minute are the particles into which matter may be divided, we are led to infer, by a number of phenomena, that the divisibility of matter cannot be continued *ad infinitum*, at least not with the means and natural forces at our command.

Every substance is, therefore, assumed to be an aggregate of smaller particles, which we term *atoms* or *molecules*. We have glasses magnifying from

1,200 to 1,600 times, but chemistry teaches us that the atoms must be still less than the smallest particle visible by means of these glasses.

If this view be followed out, we must conclude that the mass of a body depends on the number of its atoms, and that its properties are dependent on the constitution and arrangement of them.

We shall have opportunities of seeing these conclusions more or less confirmed, by results arrived at in the study of Nature.

11. The small openings in the skin, through which the perspiration escapes, are termed *pores*. Hence all bodies that are easily penetrated by air or water are termed *porous*, and as most bodies possess this property, we class *porosity* among the general properties of matter.

Sponge, wood, and charcoal, bread-crumbs, &c., are very porous bodies, the numerous and large pores they contain may be perceived at a glance, but the porosity of other bodies is only perceptible under certain circumstances. If, for instance, hollow balls, constructed of gold, iron, or other dense metals, be filled with water, closed tightly and submitted to great pressure, the water will exude in small drops through the pores of the metal

Glass, and a few other substances, do not admit the passage of air and water under any circumstances Although there may be reasons for believing even these substances to contain interstices or pores, still it is customary to consider only those bodies as porous that possess, under ordinary circumstances, the above-named properties.

12 It may be concluded, from the foregoing remarks, that *compressibility* also belongs to the general properties of matter. For, whenever a mass of matter contains spaces or interstices, it is capable of compression, provided we have at command the requisite amount of force to effect it Indeed, no body has as yet been discovered that could not be made to occupy a smaller space by the application of pressure.

It is obvious that the density of a body will increase in proportion to the amount of pressure to which it is subjected, and that the resistance offered by a body against further compression increases proportionately to the increase of the pressure applied.

The air is indisputably the most compressible of all bodies, while it is singular that water and other fluids can only be compressed to a very small extent If, for example, 20 cubic inches of water were introduced into a cannon, the sides of which were three inches thick, and an attempt were made to compress the water into a space of 19 cubic inches, the cannon would burst before this compression could be effected.

Very porous bodies naturally admit of considerable compression, but metals likewise occupy a much smaller space when hammered or coined, and even glass may be compressed to a certain extent, hence it must likewise contain pores, though they are too minute to be visible.

13 When a body is compressed by the application of an external force, its particles will evince a tendency to resume their original position. The term *elasticity* has been given to this property, and the bodies are therefore called *elastic*.

This property is possessed by bodies in very different degrees A certain quantity of air, to whatever extent and however frequently it may be compressed, will always return to its original volume, immediately the pressure is removed. Air is, therefore, perfectly elastic.

Amongst the highly elastic substances may be mentioned caoutchouc, feathers and hairs, whalebone, many kinds of wood and metals, and particularly steel.

In many substances, such as fluids, clay, &c., elasticity is scarcely perceptible, or at least only under peculiar conditions: such bodies as these are, on the contrary, termed *non-elastic*.

If an ivory ball be laid gently on a marble slab, coated with lamp-black, it will only receive a small black speck at the point on which it rests on the slab. But if the ball be allowed to fall from a height upon the slab, it will receive a round black spot, increasing in size proportionately to the height from which the ball falls. This experiment proves that the ball is flattened at the moment it touches the slab, but that, being elastic, it immediately regains its spherical form. The bow, the cross-bow, and the projectile apparatus of the ancients owe their power to elasticity. This property is most extensively made available in mechanics, and it is especially the elasticity of wires and strips of brass and steel, termed *springs*, which, as a moving power, are very generally employed. Such springs are used for gun-locks, door-locks, and pocket-knives; and it is the *spiral* springs which give to some kinds of sofas and beds their elasticity; carriages also owe their easy and characteristic movement to springs. The importance of elasticity, however, will be more readily understood, when we show, in the following pages, that watches and clocks can be set in motion by springs without the use of weights.

14. By *expansibility* of bodies we understand their property of increasing in size, and consequently of occupying a greater space when they are heated.

The space occupied by a body may be assumed to increase proportionately as the latter is heated.

Expansibility is, therefore, observed most distinctly, and to the greatest extent, in many of those substances which are not destroyed by the highest temperatures we can subject them to, as is the case with air and water. One cubic foot of water, when completely converted by heat into vapour, occupies in that condition a space of 1,400 cubic feet.

Classification of Physical Phenomena.

15. As physical phenomena are very numerous and various, it is expedient to class them into larger groups. It is evident that the characters of these groups can only be perfectly understood when we are familiar with their contents; we shall, therefore, limit ourselves at present to a brief exposition.

The first group embraces those phenomena only, the ultimate cause of which is the mutual *attraction* existing between the particles of matter.

In the second group are comprised the phenomena, arising from a peculiar motion, which we term *vibration*.

The third group consists of a series of phenomena, based on the existence of certain currents, of which we shall speak farther at the proper place.

This arrangement will be rendered more intelligible by the following table:—

I. Group.	II. Group.	III. Group.
Phenomena of Attraction.	Phenomena of Vibrations.	Phenomena of Currents.
1. Cohesion. 2. Gravity. 3. Equilibrium and Motion.	1. Sound. 2. Heat. 3. Light.	1. Electricity. 2. Magnetism.

I. PHENOMENA OF ATTRACTION.

16. All the smallest particles of matter attract each other mutually. This inherent power is, however, displayed in *three* ways, differing considerably from each other.

In the first case only those particles attract each other which are in immediate contact, a more or less powerful connexion being thereby established between them, whence this kind of attraction has received the name of *Cohesion*.

Secondly, we have to deal with the mutual attraction of particles, even when they are not in actual contact, and, indeed, when they are situated at a great distance from each other. This power is called *Gravitation* or *Gravity*.

By the third kind of attraction, which is termed chemical attraction, or *affinity*, the properties of the cohering particles are *altered;* these phenomena form a particular branch of natural science, termed *Chemistry*.

I. Cohesion.

17. A more or less powerful resistance is always met with in the endeavour to separate the particles of any substance from each other. We ascribe the adhesion of these particles with a certain strength to a peculiar kind of attraction, to which the name *Cohesion* has been given.

This power has been found, upon closer examination, to possess the peculiarity of being called into action only at *immeasurably small distances*.

If wood, metal, or glass be broken, the cohesive power is destroyed at the fractures, and cannot be restored, even if the two surfaces be placed close together very carefully. It is only with bodies the particles of which are exceedingly mobile, such as fluids, that the disjointed surfaces can come into sufficiently close contact to be made again to cohere.

The force with which the particles of a body cohere is entirely dependent upon heat, the existing cohesive force decreasing proportionately to the increase of temperature.

Assuming the entire matter composing the earth to be several thousand times hotter than boiling water, the attraction between the particles of matter would cease altogether. If, on the contrary, the temperature of the earth were a few thousand times less, all particles of matter would cohere so powerfully that it would be impossible to separate them by mechanical means.

The state of things at the ordinary temperature of our earth, however, is very different. Substances are met with the particles of which can be separated only with difficulty; these are termed *solid* substances. Of others, the particles may be easily separated, or their position altered; such bodies are called *fluids*.• Finally, there exists a class of bodies, whose particles are so far removed from each other by heat, that their cohesion appears to be entirely suspended; these are the *aëriform bodies*, or *gases*.

18. Next to heat, the *arrangement* of the particles of matter exerts its influence over the force of cohesion. Wood is known to be more easily cleavable lengthways than across the fibres; cast-steel is more brittle than wrought-steel.

Such expressions as are commonly used to denote the various degrees of

cohesion, as hard, brittle, tough, soft, ductile, plastic, semi-fluid, fluid, &c., need no farther explanation.

It is of importance, for many purposes, to be able to compare the power with which various bodies maintain their cohesion. To attain this end, pieces of the substances, of equal length and thickness, are loaded with weights, which are gradually increased, until the bodies break. The cohesion is of course the greater the more weight that is required to overcome it.

Thus, for example, 120 lbs. are required to tear asunder an iron wire of $\frac{1}{25}$ inch diameter; wires of equal thickness, made of the following metals, require the weights mentioned with each to overcome the cohesion of their particles: bar iron 90 lbs., steel 60 to 80 lbs., cast-iron 28 lbs., brass wire 60 to 120 lbs., copper wire 42 lbs., lead wire $2\frac{1}{2}$ lbs., glass tube, or rod, 5 lbs.

19. A great peculiarity in the cohesive force of bodies is its continual tendency to arrange the ultimate particles of matter with a certain regularity, so as to produce bodies limited by planes, edges, and angles, which we term *crystals*. Salt and sugar-candy are well-known examples of the result of this property.

There are a number of causes, and more particularly some other natural forces, that exert an influence adverse to the formation of crystals. Hereafter we shall make ourselves better acquainted with the conditions necessary for crystallisation.

20. If two smooth and even plates of glass or metal be laid upon each other, they will adhere together with a certain amount of force, so that the lower plate may be lifted up by means of the upper one.

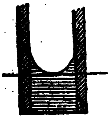
Observation teaches us that, in general, when two bodies come in contact with each other, they will cohere with more or less force.

This phenomenon is explained by the attraction exercised by the particles of the surface of the one body for those of the other body. This attraction increases in strength, therefore, in proportion to the number of particles that come into contact with each other. Indeed two balls that touch only at one point have no perceptible attraction for each other, while plates will adhere together with a strength increasing proportionately to the size and smoothness of their surfaces.

The attraction thus exercised on the surfaces of two different bodies is termed *adhesion*, and likewise exists only at infinitely small distances. This attractive force is not confined to solids alone, but is exercised between solid, fluid, and gaseous bodies, particularly air, which adheres with great obstinacy to the surface of solid bodies. The adhesion of fluids to solids is termed *wetting*. Painting, white-washing, pasting, glueing, cementing, &c., are instances of the application of adhesion to practical purposes.

21. On the other hand, it is remarkable that many fluids do not adhere either to solids or to other fluids. If a glass rod be dipped into water or oil, some particles of each liquid will adhere to it; this would not be the case with mercury. If the rod be coated with grease previously to immersion, no water will adhere, since oil and water do not mix. In fact, the oil and water, or the mercury and glass, not only appear to be devoid of this attraction, but to possess rather a repulsive force, which is ascribed to a particular power, termed *repulsion*. If, however, the mutual cohesion of the particles of water and oil

be assumed as exceedingly great compared with the adhesive power of the one liquid to the other, the above phenomena may be explained without the necessity of assuming any repulsive force.



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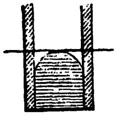

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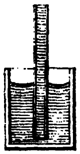
22. If, therefore, a glass-tube be dipped into water, and another into mercury, the two liquids in the tubes will not exhibit perfectly plane surfaces; the water ascends the sides of the glass-tube, by virtue of its attraction for the latter, a concave surface being thus produced, as shown in fig. 3; while the mercury, which possesses no attraction for the glass, forms a convex surface in the tube (fig. 4).



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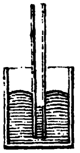

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If this experiment be made with very narrow tubes, the water will not only rise at the sides, but in the entire tube; while the surface of the mercury inside the other tube will be lower than that of the mercury outside (figs. 5 and 6).

Very narrow tubes are called *hair* or *capillary* tubes, and the force with which fluids ascend these tubes is termed *capillary force.*

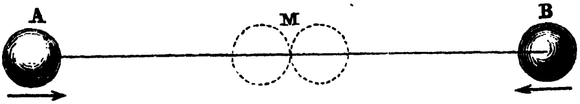
The narrower the capillary tubes, the higher fluids ascend in them, and it is immaterial of what substance they are, so long as the surface is moistened by the liquid employed. Hence porous bodies attract and retain fluids with great force, as the pores may be considered as an infinite number of irregularly aggregated capillary tubes.

Similar phenomena are exhibited by white sugar, wood, sandstone, or even a heap of sand or ashes. Walls and porous stones that are situated on damp ground always remain damp. A heap of dry sand under the same circumstances will become rapidly saturated with water to the very top. The property of lamp wicks and filtering paper of absorbing oil and water, and a number of other phenomena, may be explained by the same kind of attraction.

II. Gravity (Gravitation).

23. Gravity is the mutual attraction between different portions of matter, which acts at all distances, and the force of which corresponds to the mass of the attracting bodies.

Let us suppose the two balls A and B (fig. 7) which are of equal magnitude,



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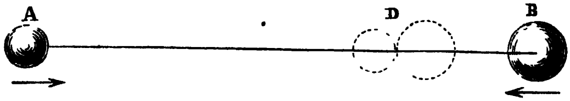
and therefore attract each other with equal force, unless influenced by any other opposing force, it is evident that both balls, following their attraction, will approach each other with equal velocity until they come in contact at the point M, which is exactly in the centre of their original distance. But if, as in fig. 8, the ball B is as large again as A, the attraction that B exercises towards A will be double that which A exercises towards B; and as the two balls approach, A will advance with double the velocity of B, and consequently pass over double the distance. Both balls must therefore meet at the point D,

which is situated at one-third of the entire distance. We thus see that the



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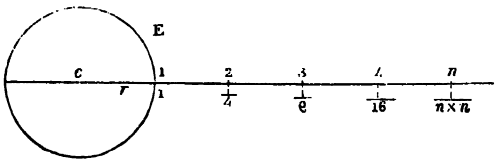
smaller ball passes over the greater distance, and this is even more evident when the difference in the size of the two balls is still greater, as in fig. 9,

9.

where A is supposed to be equal 1, and B equal 100. In this case the motion of B is so small that it apparently remains at rest while the smaller ball A advances with great velocity to the greater ball. This affords us an explanation of one of the most common phenomena, namely, the *falling* of bodies, since, all bodies existing on the surface of the earth are comparatively exceedingly small, and are attracted by it with considerable force. Hence, gravity is the cause of the *falling* of bodies, and observation has shown that when the time a body occupies in falling amounts to a second, it passes through a space of 15 feet.

If a heavy body, for example, a leaden bullet be suspended to a thread, it will certainly not be able to fall, but will draw the thread in a position which indicates the direction of gravitation (fig. 10). This position is termed *vertical*, and the simple instrument which serves to indicate it is called a plummet. The direction which intersects the vertical line at right angles is called the *horizontal* direction. The surface of water when at rest is always in a horizontal position.

24. If we suppose the direction which a plummet takes to be prolonged, we obtain a line extending to the centre of the earth, and as this is the same at every point of the earth's surface, the entire attraction of the earth E (fig. 11) appears to be concentrated at the centre *c*. Every object on the surface of the earth is, therefore, situated from the centre of gravity at a distance equal to the radius *r* of the earth, and is there attracted with a force producing a velocity in falling bodies of 15 feet in a second. The attraction is not equal at greater distances from



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the earth, but becomes weaker in proportion to the distance of the body

attracted, from the centre of the earth. This decrease in the force of gravity follows a particular law, which may be expressed as follows: the force of gravity in the distance 1 from the centre of the earth being represented by the space of 15 feet, two is equal to $\frac{15}{4}$, three to $\frac{15}{9}$, and four equal to $\frac{15}{16}$, &c. The force of gravity at any distance from the earth may be expressed by a fraction whose numerator is 15, and the denominator of which is obtained by multiplying the number of the distance by itself; or, more shortly, *the gravity decreases in proportion to the square of the distance.*

It may be now imagined that, on very high mountains, the space through which a body is carried in a second, by the force of gravity, would be less than 15 feet. But the highest mountains on the face of the earth are too small in size, when compared to the latter, to have any perceptible influence over the velocity of motion resulting from the force of gravity.

25. As gravity has equal influence over one particle of matter as over several together, all bodies must fall with equal velocity, however large or small they may be.

A piece of paper, a feather, or a straw, are, however, observed to fall less rapidly than a stone or a leaden bullet: the only reason of this is the greater resistance of the air against the former; if, therefore, the above-named bodies were to be placed in a *vacuum* and allowed to fall, they would all do so with equal velocity.

26. The motion of a falling body is continually accelerated; for if we assume a body to receive, through the force of gravity, a certain velocity for a particular period, it will retain this velocity unaltered for every succeeding period, even if gravity had no longer any influence over it. We know, however, that the latter continues to exercise its force and to increase the velocity of the motion unceasingly. If, therefore, a body falls 15 feet in the first second, the distance it travels in the first half of that time must necessarily be less than that which it describes in the second half, and at the end of the second the velocity of its motion must be greater than at any preceding time. Hence it follows that a body must attain a rapidly increasing velocity for every succeeding second that it falls; according to a law established by calculation as well as observation the space through which a body falls in a certain number of seconds may be found by squaring the number of seconds, and multiplying the result by 15. The law of falling bodies must therefore be expressed thus: *the space through which a body falls increases in proportion to the square of the time it occupies in falling.*

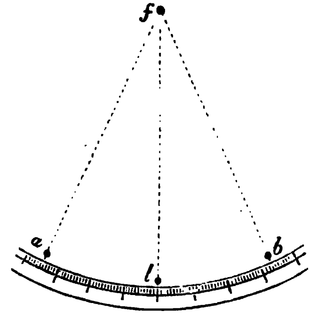
If a stone be thrown into a well, and four seconds elapse before it is heard to touch the bottom, the depth of the well will be $4 \times 4 \times 15 = 240$ feet.

THE PENDULUM.

27. A heavy body, such as a ball or disc of metal, fastened to the end of a string, represents a pendulum.

If we bring the pendulum from its vertical position or equilibrium, *f e*, fig. 12, so that the ball be situated at *b*, and then leave it to itself, it will fall to the point *l*, and then rise on the opposite side to *a*, which is situated, almost imperceptibly, lower than *b*. When the ball has arrived at *a* it will again fall, and rise once more on the other side, without, however, reaching exactly to the point *b*; and thus the motion, which is termed the oscillation of the pen-

dulum, will continue, each oscillation being slightly less than the preceding one, until at last the pendulum will be once more at rest. More accurate observation shows that oscillations of the pendulum are dependent upon gravity, and are only slightly changed motions of falling. Attracted by the earth, on the one side to b, and on the other side maintained in one unchangeable distance from the point of suspension by the thread, it is drawn by these two forces in a circular course in which the pendulum, according to the law enunciated at § 26, falls with increasing velocity towards the lowest point l. The pendulum would remain at rest in the position $f\,l$, which is the direction of gravity, if it had not acquired a certain velocity by falling from b to l. With this velocity, continually diminishing by the influence of gravity, it now rises on the other side, until it is overcome, when the pendulum again begins to fall from the point a. Were it not for the friction at the point of suspension, and the resistance of the atmosphere which together brings it at last to rest, the oscillations of the pendulum would continue for ever.



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Some laws concerning the oscillations of the pendulum have been deduced, of which the most important points are expressed in the following:—

(1.) The single oscillations of one and the same pendulum are of *equal duration*, whether the rise be greater or smaller, supposing that the arc $a\,b$ does not amount to more than five degrees.

(2.) Two pendulums of equal length perform an equal number of oscillations in the same period.

(3.) Two pendulums of unequal length perform an unequal number of oscillations in the same period, the longer pendulum performing the smallest number.

(4.) One and the same pendulum always makes in a certain time the same number of oscillations, when the force of gravity acts in the same manner and with equal power. If we were able to place the same pendulum, which on the earth makes in a definite time a certain number of oscillations, upon the moon and the sun, and there observe it, it would make in the former fewer and in the latter many more oscillations, since the moon exercises fifty times less, and the sun nearly one and a half million times greater, attraction than the earth.

28. These laws have led to applications of this simple instrument, which render it one of great importance. In the first place, the pendulum serves in clocks to rectify the unequal motion which is produced either by weights or springs, and likewise to furnish a measure of definite and unalterable length.

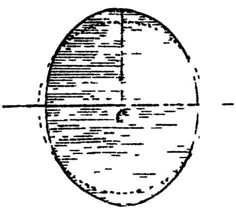
29. The *seconds' pendulum* is one that describes exactly sixty oscillations in one minute, each oscillation having the duration of a second. It is obvious, from what has just now been stated, that this pendulum must be of a certain length; for if it were too short it would describe more than sixty oscillations in a minute, and a smaller number if it were longer.

Hence the seconds' pendulum of any particular place may be used as a certain, invariable measure of length. In Paris this pendulum must have exactly the length of three Parisian feet and eight lines. It is, therefore, only two and

two-thirds lines shorter than the meter. In London the length of the seconds' pendulum is 39·13929 inches.

30. The observation that one and the same seconds' pendulum did not perform an equal number of oscillations in one minute at all parts of the surface of the earth, created a great deal of surprise amongst philosophers. On taking the Parisian seconds' pendulum, three feet eight lines in length, to the equator, for instance, it was found to perform a smaller number of oscillations than sixty in one minute, whereas, in the neighbourhood of the North Pole, it performed a larger number.

As the movements of the pendulum are dependent on the force of gravity, and as the latter force decreases (§ 24) as the distance from the centre of the earth increases, the observations with the pendulum led to the conclusion, that a point at the equator must be more distant from the centre of the earth than a point at the poles. Hence the earth can be no perfect sphere, but appears to be somewhat depressed at the poles, as shown at fig. 13. The diameter of the earth at the equator is 7935 miles, at the poles it is only 7900 miles. The centrifugal force which the earth receives from its revolutions, likewise contributes to the decreasing of the oscillations of the pendulum at the equator.



13.

Weight.

31. As every particle of a body is attracted by the earth, it must necessarily exercise a certain amount of pressure upon any support on which it may be placed. The total pressure of all the particles of a body on its *horizontal* support is termed its *weight*. Hence the greater the *mass* of a body (*i. e.* the larger the number of particles of which it consists) the greater is its weight.

The masses or weights of two bodies may be compared by suspending them to the two ends of an equal-armed lever. If the latter remains in equilibrium, the weight of the two bodies is equal. If the two weights are unequal, the heavier one is denoted by an inclination downwards of that arm to which it is suspended.

An arrangement of this description for the comparison of weights is termed a *balance*.

32. By *weights* are also meant the various units of masses, employed in different countries to weigh with, *i. e.* to determine and express the masses of bodies in general.

The *gramme* (15¼ grains) is the comparative unit of weight most generally employed in scientific researches. It is represented accurately by the amount of water, at a temperature of 4° C. (39·2 F.), required to fill a vessel in the form of a cube, whose sides are one centimeter (0·39 inch) in length, and which, therefore, contains one cubic centimeter (0·61 cubic inch) of water.

If, therefore, a certain substance is said to weigh 80 grammes, we mean thereby, that if it be placed in one pan of a balance, 80 cubic centimeters of water will be required in the other pan to maintain it in equilibrium. It is obviously far more convenient to substitute for the water small pieces of metal, each of which corresponds exactly to one cubic centimeter of the former.

33. The general unit of weight in commerce is the pound. It would be exceedingly convenient if this weight were equal in all countries: this is, however, by no means the case, as will be seen by the following table:—

1	pound	is equal to	453	grammes in	England.
1	kilogramme	,,	1000	,,	France.
1	pound	,,	560	,,	Austria and Bavaria.
1	,,	,,	500	,,	Hesse Darmstadt and Baden. This is the pound adopted by the German Zollverein.
1	,,	,,	484	,,	Hamburg.
1	,,	,,	467	,,	Prussia, Saxony, Hanover, Wurtemberg, Electorate of Hesse, Brunswick, and Frankfort-on-the-Maine. This pound is also called the *Cologne* light pound.

Density.

34. It might be expected that, on placing a cubic inch of water in one pan of a balance and a cubic inch of lead in the other, these two substances would hold each other in equilibrium, their masses being of equal extent. This, however, is well known not to be the case; indeed, as many as 11 cubic inches of water are required to retain one cubic inch of lead in equilibrium. If mercury were substituted for lead, 13 cubic inches of water would be required, and one cubic inch of gold would even require 19 cubic inches of water to maintain it in equilibrium.

If the same experiment be made with one cubic inch of water and the same quantity of alcohol, it will be found, on the contrary, that the quantity of spirit must be increased, or that of the water diminished, in order to obtain equilibrium. Oil of turpentine, poppy-oil, and other oils, stand to water in a similar relation.

These facts clearly prove that different bodies contain a different number of atoms in an equal space. This may be easily imagined, if we conceive the atoms to be placed more or less closely together. One cubic inch of lead contains undoubtedly eleven times the mass of one cubic inch of water, and, therefore, weighs eleven times as much as the latter. Turpentine and other oils are, on the contrary, not so heavy as water.

The densities of most fluids and solid bodies have been compared with that of water; and the number expressing the amount that one cubic inch of a body is heavier or lighter than the same amount of water, is called the density or the *specific gravity* of the body. The following are the specific gravities of a few well-known bodies:—

Substance.	Specific Gravity.	Substance.	Specific Gravity.	Substance.	Specific Gravity.
Cork - - - -	0·24	Milk - - - -	1·030	Chromium - -	5·900
Poplar wood - -	0·38	Oak wood - -	1·170	Antimony - -	6·712
Lime-tree wood -	0·439	Phosphorus - -	1·770	Zinc - - - -	7·037
Pine wood - -	0·555	Sulphuric acid -	1·848	Iron (wrought) -	7·788
Nut-tree wood -	0·677	Ivory - - -	1·917	Steel - - -	7·816
Ether - - - -	0·713	Sulphur - - -	2·03	Copper (wrought)	8·878
Alcohol - - -	0·793	Quartz - - -	2·6	Bismuth - -	9·820
Oil of Turpentine	0·872	Basalt - - -	2·66	Silver - - -	10·474
Poppy oil - -	0·929	Bottle-glass - -	2·60	Lead - - -	11·852
Ice - - - -	0·916	Granite - - -	2·80	Mercury - -	13·598
Water - - - -	1·000	Diamond - -	3·52	Gold - - -	19·325
Sea-water - - -	1·026	Heavy spar - -	4·426	Platinum - -	22·100

35. The advantage to be derived from a knowledge of the above numbers may be easily proved.

For instance, as every substance invariably possesses a uniform density under equal conditions, we arrive at one of the most important means of recognising a body. In purchasing pure silver, each cubic inch should weigh 5·237 ounces. Should its density be less, the silver may be assumed to contain copper; if it be greater, lead may be present. If a structure of oak weighs 1,170 lbs., a similar one, of exactly the same cubic contents, made of deal, would weigh only 555 lbs. A bottle, capable of containing 10 lbs. of water, will hold 18 lbs. of sulphuric acid, the latter being nearly twice as heavy as the former.

In every-day language those bodies are termed *light* that occupy a comparatively large space and contain a small amount of mass, as, for instance, cork, and several other substances.

Air is far lighter than all solid and liquid bodies. It will be seen hereafter in what manner the density of gaseous bodies is determined.

III. Equilibrium and Motion.

36. A body is said to be in *motion* when it occupies different positions at different times. It must thus continually change its place in relation to surrounding objects, and this enables us to recognise the motion. The hand of the clock traverses from number to number, the ship passes by valleys and hills, the railway-train hurries through town and country,—these bodies are in motion, since we observe that they pass by neighbouring objects, and approach those which are in the distance.

On the other hand, the mighty mountain appears to us fixed and motionless, the mass of a building immoveable, and the tree firmly rooted in the ground. This motionless condition of a body and its members remaining always at the same distance from surrounding objects we call *rest*.

37 From what has been said it is essential to the perception of motion that certain objects should appear as being at rest because if all objects were moving at the same velocity, they would all appear to be at rest, since their relative position would remain unchanged, as we perceive by gazing at the star-bespangled heavens, the mountains, forests, and towns, on the surface of the earth

But observation teaches us that all the heavenly bodies, even the fixed stars, which by reason of their inconceivable distance appear to us as being motionless, are in perpetual movement, and we may with safety assume that not a single particle of the universe is ever at perfect rest We know by the daily rotation of the earth, that mountains, forests, and cities, participate in this motion.

There is hence no *absolute* but only *relative* rest. When travelling in a vessel, our bodies, in relation to objects immediately surrounding us, as the masts, tables, and chairs, may be at rest, whilst a single glance at the objects on the shore which one by one disappear from our view, convinces us that the vessel and all it contains are in rapid motion.

38. If we inquire into the causes of motion, they are numerous. The force of gravity is the only, or at least co-operating cause of most phenomena of

motion. Other moving powers are electric and magnetic attraction, the influence of heat, and finally that power by means of which men and animals are enabled to set in motion not only their own bodies, but also other objects, and which cause the peculiar vital phenomena in plants and animals. But for the general consideration of the laws of motion, it is quite immaterial on which cause these motions depend.

39. As the first and most important law of the science of motion, or *mechanics* of inanimate matter, is the following:—

1. *A body at rest cannot impart motion to itself.*

2. *A body in motion cannot by itself change or annihilate this condition of motion.*

Both these principles convey a more accurate expression of the *inertia* of matter, already alluded to in § 9.

40. If any body be set in motion, it would, according to the second principle, continue the motion imparted to it unimpaired *ad infinitum*, as is actually the case with the heavenly bodies. But within the sphere of the earth's influence, we cannot impart to any object such a continuous motion. If, for example, we fire a ball, with the strongest charge of powder, into the air, or roll it over a smooth surface of ice with a velocity the eye can scarcely follow, its motion will become gradually slower, and at last cease altogether. In both cases the ball does not of itself come to a state of rest, but there are other forces, such as the resistance of the air and the attraction of the earth, which put an end to the motion.

41. In the farther consideration of motion, we have first to consider its relation to space and time, namely, its *direction* and *velocity*.

The distance from the point at which the motion of a body begins to that where it ceases, is termed its way, or course, and the line which indicates this way is called its *direction*. This is either a continually unchanged *straight* line, or it is a *crooked* line. The circular motion which the points of a body describe around itself is called *rotation*.

42. By a comparison of the distance with the time which the body requires to describe it, we arrive at the *velocity* of motion.

There is a great variety in the degrees of velocity. For instance, the minute-hand of a watch describes the same distance in one hour which the hour-hand accomplishes in twelve. In one second a snail travels one line, a rapid runner 25 feet, a race-horse 50 feet, a gale of wind 124 feet, a cannon-ball 600 feet, sound 1,000 feet, and light 195,000 miles.

43. The velocity of *molecular motion* is inappreciable. We often find that the individual particles of a body describe a distance so exceedingly small, that we are not enabled to take cognizance of their motion, although we perceive the changes in the object which are the result of this motion. This occurs when a body is expanded or contracted by the influence of heat, by crystallization, by chemical combinations, and by the development of plants and animals. As the smallest particles of bodies are termed *molecules*, the force extending only to those particles which are in immediate proximity and acting at immeasurably small distances, has received the name of *molecular force*.

44. Investigation teaches us that velocity is either *equal* or *unequal*.

In the case of equal velocity, the same distance is traversed in the same space of time, be the space ever so small. If, therefore, a body traverses a mile in

the hour, it must traverse the sixtieth part of a mile in a minute, and three thousand six hundredth part of a mile in a second.

Equal motion requires that the moving body be under the influence of a continuous moving power, which accurately counterbalances opposing forces, so that the original velocity remains unchanged.

The velocity of a body in motion is said to be *unequal* if it increases or decreases at every consecutive moment; hence in the first case it is called *increased* or *accelerated*, and in the second *decreased* or *retarded* velocity.

Accelerated velocity occurs when, on a body already in motion, a force acts continually in the same direction, as in the case with falling bodies (§ 26), and the descending pendulum (§ 27). In the case of retarded motion, a force continually opposes the body in motion, for example, as the force of gravity opposes the motion of a stone when thrown into the air, and that of the rising pendulum.

45. From what has been said, it follows that a body which moves with accelerated velocity during one minute, has in the second second of time a greater velocity than in the first, and in the third second greater than in the second second, &c. If at any part of the time that the body is in motion the accelerating force ceases to act, the body continues its motion uniformly with that velocity which it had at the moment of interruption, and which is called its *final velocity*. On the other hand, we understand by the term *mean velocity*, that velocity which a body would have if we suppose the accelerating power to be removed exactly in half the time the body is in motion. If a body fall during the space of a second, it attains a final velocity of thirty feet, and its mean velocity is fifteen feet. If it had had this latter velocity at first, and had continued it *uniformly*, it would have described the same distance in one second, as the body falling with accelerated motion would have traversed in the same space of time, namely, fifteen feet.

46. The power of a force is shown by its action. Let us suppose a strong strip of elastic steel, similar to those which are employed for cross-bows: the farther the force is capable of bending the steel, the greater will be its power. Indeed, elastic metallic strips are employed in the manufacture of *dynamometers*, by means of which various powers may be compared, as, for example, that of men and horses, with weights. We also frequently judge of power by the weight of a mass which is lifted or moved. But in the latter case we must also take into consideration the velocity, two forces being equal if they impart to corresponding masses the same velocity, or if the masses are in an inverse ratio to the velocity imparted to them. This is the case when the numbers obtained by multiplying each mass with its velocity are equal: for example, a mass represented by 4 has a velocity 2, and the mass 2 has the velocity 4. In both cases the product of multiplication = 8. The product obtained by multiplying the mass of a body, which is moved, by its velocity, is generally called its *momentum*.

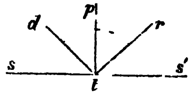
If a body in motion come in contact with another, a *blow* is the result. Thus numerous phenomena may arise, according to the substance, the size, the direction, and the velocity of the bodies in question. It may in general be said that soft unelastic substances receive a permanent, and elastic bodies only a transitory flattening, and that a blow exercises its entire force only when directed against the centre of gravity of the object which is struck.

The behaviour of hard bodies when struck may be exhibited in a very beautiful manner with balls of ivory suspended by threads.

47. If a body in motion come in contact with a second body of equal size at rest, the motion of the first will cease completely, while the second body will move with a velocity equal to that of the first. If the mass of the body at rest be larger than that of the one originally in motion, the velocity imparted to the former will be less than that possessed by the latter, and *vice versâ*. A large mass, moving with a small degree of velocity, will, therefore, impart to a small mass a high degree of velocity, and, on the other hand, a very small ball, moving with extraordinary velocity, will, if it meet with a large ball, scarcely set it in motion.

Such small bodies are hailstones and shot, which acquire their destructive properties solely from the velocity with which they travel.

If an object fall perpendicularly upon a plane $s\,s'$ (fig. 14), it will, in consequence of the mutual elasticity, rebound in the same direction; but, on the other hand, if the blow takes place at an acute angle $r\,l$, the striking object will rebound at an equal angle $l\,d$. A practical application of this is frequently seen in playing at billiards, and in the ricochet firing of artillery.



14.

48. Motion is not imparted simultaneously to every particle of a body, but at first only to the particles which are directly exposed to the influence of the force, for instance, of a blow. From these particles it spreads to the rest. A slight blow is sufficient to smash a whole window-pane, while a shot from a gun will only make a small round hole in it, because in the latter case the particles of glass that receive the blow are torn away from the remainder with such rapidity, that the motion imparted to them has no time to spread any farther.

On this also depends the method of fastening a hammer upon its handle, by knocking the latter on the ground, and the well-known trick of placing a small coin on a ring perpendicularly over the mouth of a bottle (fig. 15). If the ring be rapidly pushed from under it, the coin will fall into the bottle.


15.

49. If several forces act simultaneously upon an object, without producing the slightest change in its condition, their actions completely neutralize each other, and in this case the forces are said to *maintain each other in equilibrium*, or in other words, the body is in equilibrium. In this case it is perfectly indifferent whether the body be in a state of rest or in motion. If a locomotive engine, proceeding at a uniform rate, arrive at an ascent, and its steam-power is increased at a rate corresponding to this impediment, the engine continues its way at its previous speed,—both powers being, as it were, not in existence, since they maintain each other in equilibrium.

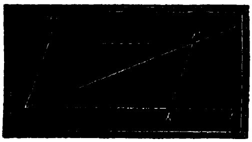
We must, however, distinguish this *equilibrium of forces* from the equilibrium of bodies,—that is, the position which solid, liquid, and gaseous bodies assume under the influence of gravity, and to which we shall refer at a subsequent page.

50. If two or more forces, not in equilibrium with each other, are brought

to bear upon one body, a motion will be imparted to it. It must be borne in mind that a body always moves in *one* direction only, whatever may be the number of forces that are brought into operation.

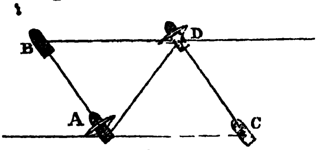
This point may be most easily comprehended by assuming a body to be under the influence of *two* forces. In this case, the body does not move in the direction of either force, but in one that lies between these two directions. This kind of motion is termed *compound*, and the line which indicates the direction of this motion is termed the *mean* or *resultant*.

The *resultant* of two forces is easily found. In fig. 16 we have two forces acting simultaneously on the point *a* in two directions *a x* and *a y*. The lines *a b* and *a c* represent the directions and distances which the body would have travelled under the influence of each separate force. Let the lines *c r* and *b r* be drawn from the terminating points *c* and *b*, parallel to the direction of the forces. The line from the point *r*, where the two lines intersect each other, to *a*, is the mean or resultant of the forces *a b* and *a c*, and denotes not only the direction of the force, but also the distance described by the body under its influence.



16.

Figure 17 furnishes us with an illustration of this compound motion. A ship, urged obliquely across a river from A to B by the action of wind and rudder, is propelled, however, by the stream from A to C. If the two parallels B D and C D be drawn, the line A D denotes the direction and distance which the vessel really describes.



17.

From these examples, it will be seen that by this process a parallelogram is each time formed by the given lines which represent the forces, the diagonal of which is the mean; hence it is also called the *parallelogram of forces*.

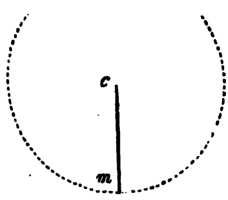
The point to which a body arrives, under the influence of two forces, may also be found by dividing the time during which they act into two equal parts, and by assuming that in the first half of the time one force exclusively acts, and in the second half the other force only is in operation. It will be readily seen that each given force may be substituted or decomposed by two other forces acting in a suitable manner. If, as in fig. 16, the two forces *c a* and *b a* may be substituted by their mean *r a*, it follows, on the other hand, that if the force *r a* be given, its action might be substituted by the two forces *c a* and *b a*.

51. Curvilinear motions generally arise if several forces act on a body simultaneously. As, for instance, a body propelled with a certain velocity, in a horizontal direction is simultaneously acted upon by the force which moves it in this direction, and by gravity which draws it vertically to the earth. The course resulting from these forces is *curvilinear*, and deviates more or less from the horizontal direction, according to the ratio in which the two forces stand to each other.

It is well known that a marksman who fires at a distant object, aims rather higher, to counteract the influence of gravity upon the ball.

52 If a blow be given to a ball, *m* fig 18, suspended to a thread, it would move in a horizontal direction if it were not attached to the thread and drawn by the latter towards the point *c*. The resulting motion of the ball will be circular

It is obvious that if any other force, in place of the thread, attract *m* continually to *c*, the result will be always a similar circular motion.



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The force that acts towards the central point *c* may be termed *centripetal*, and that which exerts its influence at right angles with the latter, the *tangential force* The line of motion described by a body under the simultaneous influence of these two forces is obviously dependent on their mutual relation In circular motion, the following is the relation between the forces the square of the tangential velocity must be equal to the diameter of the circle multiplied by the central velocity If the first product were greater than the second, the resulting curved motion would not be circular but *elliptic*, if it were exactly twice as great as the second product, the motion would be *parabolic* and if the first product were even larger still, the body in motion would describe a *hyperbola* These are all different forms of curved motion, which will be more minutely described at a future period

The most stupendous examples of these various kinds of motion are afforded us by the paths described by the celestial bodies Thus the moon is always under the simultaneous influence of two forces, namely, the attractive force of the earth, and a second acting at right angles to the former and propelling the moon at the rate of about 200,000 feet in one minute If the attractive force of the earth were alone active, the moon would approach it, in a vertical direction, 15 feet in the above space of time The resultants of *both* forces is the elliptical path which the moon describes

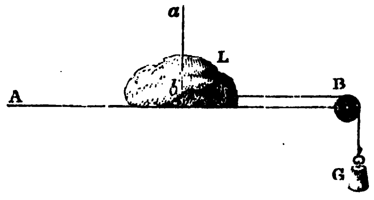
53 The science that treats of the celestial bodies and their motions is called *Astronomy* It is, properly speaking, a branch of Physics, but the great number and high importance of astronomical phenomena render it, however, necessary to devote a special section of this work to their consideration

54 In the case of the *oblique plane*, it is necessary to resolve one force into two others (§ 50) But before we investigate this subject, some preliminary remarks are necessary.

It has been stated in § 31 that the pressure a body exercises upon a *horizontal* plane, in consequence of gravity, is called the *weight* of that body If in this case we move the object, it is by no means its weight that we have to overcome, as this is supported by the horizontal plane, but only the friction of the object on the plane, and the smoother the two surfaces the smaller the friction will be. In the following observations we shall entirely disregard the friction, and assume that it is of no influence, but which never in reality is the fact In this case even a very small force must be sufficient to move a body, the weight of which is borne by its support

The small weight G, for example, may be just sufficient to move the body L (fig 19), upon the plane A B, on which the line *a b* represents the entire pressure which L exercises upon A B. But if we give this plane the inclined position represented in fig 20, the weight G is by no means sufficient to move

the object L in the direction A B. The object will, on the contrary, slide down in the opposite direction towards A, exactly as if a force at K drew it



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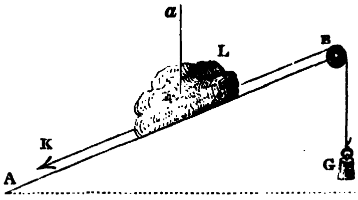
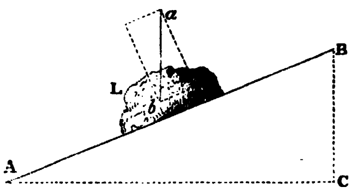


20.

down in a direction parallel to the plane. From this it follows that the plane no longer sustains the entire weight of the object, and that, consequently, the pressure which it bears must no longer be represented by the line *a b*, but by one that is shorter. But as the body remains intact, and has lost nothing of its weight, it is clear that that portion of its weight which no longer acts as pressure upon the plane manifests itself as a force which pulls down the object in a direction parallel to the plane.



21.

The force *a b* with which the body L presses upon the horizontal plane A B (fig. 19), is, therefore, in the case of the oblique plane A B (fig. 21), resolved into two forces, namely, into the force *a c*, which acts as a vertical pressure upon A B, and into the force *c b*, which is directed downwards parallel to A B.

If we call A B the length and B C the height of the inclined plane A B, it can be proved by the laws of geometry, from the similarity of the triangles *a b c* and A B C that the downward propelling force *b c* is in the same proportion to the weight of the body *a b* as the height B C of the inclined plane is to its length A B. If, therefore, the height B C be the fourth, fifth, or sixth part of the length A B, the force *b c* will be equal to the fourth, fifth, or sixth part of the weight of the body.

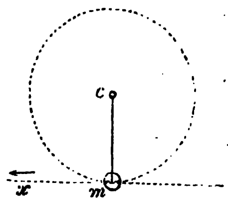
55. The application of the laws of the inclined plane is seen in the lifting of heavy weights to a certain height, in ascending and descending mountains, in architecture, &c., and the facility thus afforded is the greater the less the height is in comparison with the length, or, as it is generally expressed, the smaller the *incline*, which ought not to exceed 5 per cent. in roads and $\frac{1}{3}$rd of a per cent. in railways.

Besides the inclined plane has found application in a number of our instruments and tools. The blades of knives, chisels, and axes consist of two inclined planes joined together, as is also the case with the *Wedge.*

An inclined plane wound round a cylinder is termed a *Screw.* Gimlets, corkscrews, the Archimedian screw, and the screw that has lately been applied in propelling steam-vessels, are all applications of the inclined plane.

The more minute examination of these screws belongs to *Mechanics.*

56. If a ball, *m*, attached to a thread, be set in rapid circular motion round the central point *c*, and the thread be then suddenly severed, the ball will fly off from the central point. The direction taken by the ball is described by a line, the position of which is at right angles to the direction of the thread at the moment when the ball flies off. If, for instance, the ball be situated just at the point *m* when it flies off, it will move in the direction *m x*.



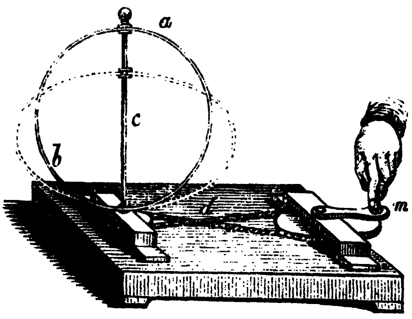
22.

The velocity with which the ball moves, on being detached from the thread, is in direct ratio to the velocity of the original circular motion.

This force is often made use of by children in throwing balls attached to a string to a great height.

A still more general application of this phenomenon is seen in bodies which *rotate*, or in other words, turn on their own axes. In this case all those parts of such a body, which do not lie in its axis, describe circles round it, and acquire a tendency to fly off from the axis, which is called *centrifugal force.* As in such rotations all particles describe their way round the axis in the *same time*, the particles farthest distant must have a greater velocity, and consequently a stronger centrifugal tendency than those which are nearer to the axis.[1] Such a body is the *earth*, which rotates round an axis, the terminating points of which are called the *poles.* Hence it follows that those portions of the earth which are situated near the equator must possess a greater centrifugal force than those which are nearer to the poles.

The action of the centrifugal force can be manifested only when it is greater than the cohesion of the rotating body, particularly, therefore, in those the mass of which is soft, or which possesses moveable particles. By means of the *centrifugal machine* (fig. 23), a series of beautiful experiments may be made to illustrate these facts, and the cause of the flattening of the earth in particular may be shown by an elastic brass hoop *a b*. (Comp. § 30.)



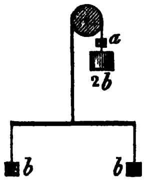
23.

Parallel Forces.

57. We meet with a series of interesting phenomena which are of particular practical importance in investigating the results which take place when parallel forces act upon a body.

The forces employed in the following examples are weights, which act in the first place at right angles upon a straight and inflexible line. We use for this purpose a rod, which is suspended by its centre *c* (fig. 24). The action of the forces is best represented if we leave out of consideration the influence of

gravity upon the rod, and this is counterbalanced by fastening to the string passing over a pulley a weight a, equal to that of the rod. We call the horizontal position which the rod now has the *position of equilibrium*, and the point to which it is fastened.its *fulcrum*.



24.

If we allow the two forces b b to act at equal distances from the fulcrum, they will, of course, draw down the rod with a power equal to $2\,b$. But this effect will be completely neutralized if we allow a weight equal to $2\,b$ to act on the other side of the pulley in an opposite direction. Neither the horizontal position of the rod, nor its situation, suffers the slightest change, hence the forces acting upon it are in perfect equilibrium. The same will be the case if we now allow the two forces b and b to act on the centre of the rod.

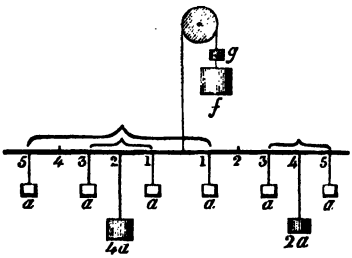
From these experiments we draw the following important conclusions:—

(1.) The effect of two equal forces upon a line is neutralized by a force equal to their sum, acting at the centre in an opposite direction.

(2.) The effect of two equal forces, acting on a line, may be substituted by a force equal to their sum acting at their common centre.

(3.) Two equal forces, acting at corresponding distances from the fulcrum, maintain each other in equilibrium.

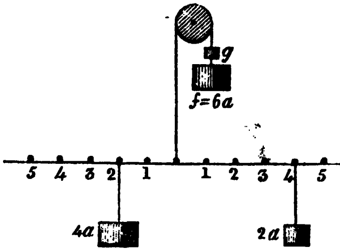
58. Figure 25 represents another rod, the weight of which is counterbalanced by the weight g. The six equal and parallel forces a act at equal distances upon the different points, and are counterbalanced by the weight f, which is equal to $6\,a$.



25.

Without destroying the equilibrium of this arrangement in the slightest degree, the weights 3 and 5 may be removed from the one side, and combined in the central point at 4 (according to § 57, 2). In like manner the weights 1 on the one side, and 5 on the other side, together with 1 and 3 on the one side of the rod, may be combined at their mutual central point 2, from which, therefore, 4 a are suspended.

We will now take into consideration figure 26. The weights with which the rod is loaded, and their distances from its central point, are unequal, and yet the whole is in equilibrium.



26.

It will, however, be observed, directly on examining the figure, that the smaller force $2\,a$ acts at a distance of 4 from the central point, while the larger force $4\,a$ only acts at the distance 2. The distances 4 and 2 bear an inverse ratio to the forces $2\,a$ and $4\,a$.

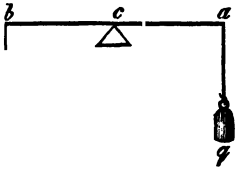
Unequal forces, acting parallel on a straight line, retain each other, therefore, in equilibrium, if their distances from the fulcrum bear an inverse ratio to the

forces; or, in other words, *if the force and distance on the one side, multiplied by each other, are equal to the power on the other side, multiplied by its distance.*
In the above example, $2 \times 4 = 8$, and $4 \times 2 = 8$.

59. It will now be easily understood that a large weight, near to the central point of a rod, may be moved by a very small force applied on the other side, at a great distance from the centre.

The above is the case in the application of the *Lever*, which is nothing more than a rod placed on a solid point of support, or *fulcrum*, while two other points are acted upon by the load and the force. The following kinds of levers are distinguished by the relative position of these points.

(1.) The *equal-armed lever* (fig. 27). Its fulcrum lies in the centre at *c*. The arms *b c* and *c a*, being equal, a small weight cannot in this case maintain a larger one in equilibrium. The principal applications of this lever are in the balance and pulley.



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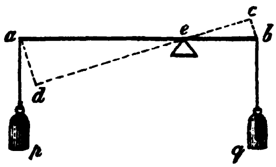
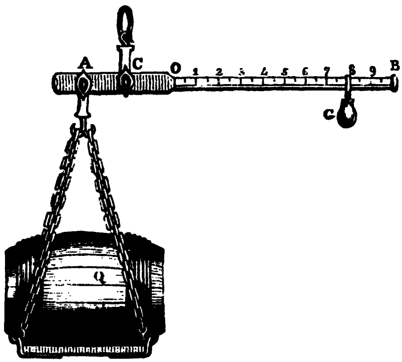


28.

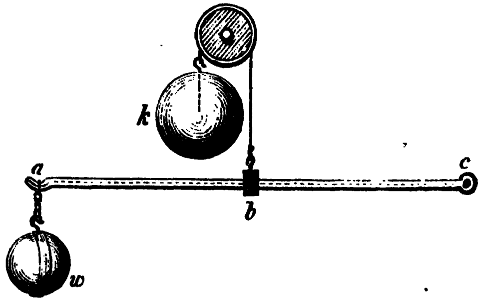
(2.) The *unequal-armed lever* (fig. 28), of which the arm *a c* is longer than the other, is applied in various ways, for moving great weights with a smaller power. One of the most familiar examples of the principle of this lever is that of two boys of unequal size wishing to swing upon a board; in order to accomplish this, the *lighter* boy chooses the *longer* end.



29.

Other applications of this lever are: the ordinary lever, the crow-bar, the windlass, the reel, the steel-yard with sliding weights (fig. 29), the weighing machine, the wheel and axle, the crane, borers, keys, scissors, &c. By due examination the principle of this lever may be traced in all these instruments.

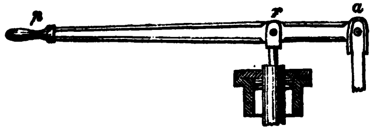
(3.) The *single-armed lever* (fig. 30) differs somewhat from those already considered, the fulcrum *c* being situated at the end of the lever. The forces *k* and *w* act on the unequal arms



30.

b c and *a c*, but in contrary directions, for *k* acts *upwards*, and *w* draws *downwards*. Equilibrium is likewise established in this case if $k \times b\,c = w \times a\,c$.

Applications of the one-armed lever are found in the chopping-blade, the nut-crackers, in most lever presses, in the force-pump (fig. 31), and in many safety valves (fig. 32), wheel-barrows, &c.



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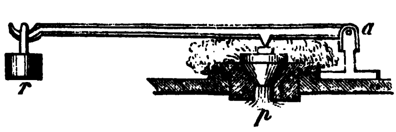
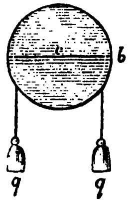


32.

60. In the *fixed* pulley (fig. 33), the forces *q* and *q* act at the points *a* and *b*, and the line *a c b* represents nothing more than an equal-armed lever, whose point of support is at *c*. No power is gained, therefore, in employing the fixed pulley; it is only of use in permitting the application of the force at the most appropriate point, as, for instance, when applied to a draw well.

The *moveable* pulley (fig. 34) represents a one-armed lever (compare § 59), the fulcrum of which is situated at *b*, while the force *q* draws downwards at the distance 1, and the force *e* upwards at the distance 2 and at the point *d*. As, however, the latter force acts at double the distance, it is only required to be half as great as the force *q*, in order to maintain the equilibrium. If, therefore, a weight of 4 lbs. be suspended on the hook of the moveable pulley, a force equal to 2 lbs.



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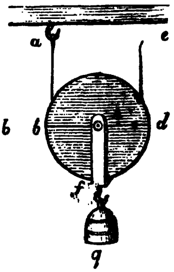

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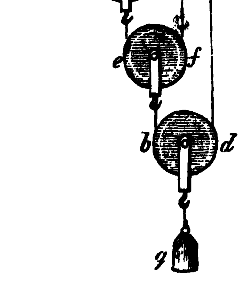

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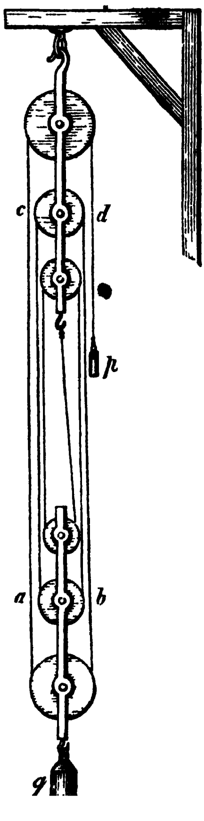


36

applied at *e* will be sufficient to raise it, and the least excess of power will be sufficient to set the load in motion.

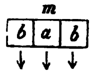
By combining a number of moveable pulleys, as seen in fig. 35, we are enabled to raise a considerable weight by the application of a small amount of force. On suspending the weight *q*, equal to 8 lbs., to a system of three moveable pulleys, 1 lb. will be found sufficient to maintain it in equilibrium. As was shown at fig. 34, the weight of the suspended load decreases one-half for every additional moveable pulley.

The most convenient arrangement for raising weights by means of moveable pulleys, is shown at fig. 36. In this system the three upper pulleys are stationary, and the three lower ones moveable; and, therefore, the advantage in its application is, likewise, that the load *q* may be counterbalanced by the application of one-eighth of its weight at *p*.

It might be expected that by the application of a great number of pulleys, we should be enabled to raise enormous weights with ease. But the results obtained fall short of expectation, partly because, by the addition of every pulley, the distance to which the load may be raised is diminished, while the friction, which is, as we shall presently find, a great impediment to motion, is proportionably increased.

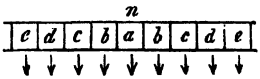
Centre of Gravity.

61. The body *m* (fig. 37) may be considered as composed of the three parts, *a*, *b*, *b*. Each of these parts is attracted to the earth in the direction of the arrows in the figure, which it will be seen are parallel to each other. We have seen at § 57, that the action of two equal parallel forces on a line may be counterbalanced by the application of a force acting in the opposite direction, and possessing a power equal or superior to that of the combined forces; we are able, therefore, to prevent the body *m* from obeying the force of gravity, *i. e.* from falling, by suspending or supporting it at the point *a*.



37.

It follows from this that we are likewise able to counteract the whole of the forces acting on each single part of the body *n* (fig. 38) by supporting the part *a*; and it is found not only by theory but also by experience that one point must exist in every body, of whatever form it may be, in which the sum of the forces of gravity, acting on all the particles, may be considered as united. This particular point is called the *centre of gravity* of the body.



38.

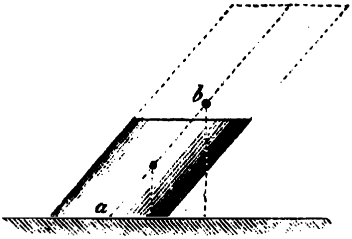
When the centre of gravity of a body is supported it cannot fall, and is, therefore, in a state of equilibrium.

62. In bodies of regular form, such as a ball, a cube, a cylinder, or a prism, the centre of gravity is always identical with the mathematical central point of the body. In irregularly-formed bodies it is always situated near the largest portion of the mass. In pyramids and cones the largest mass is evidently at their bases. In these bodies the centre of gravity is consequently found to be at one-fourth of their height.

63. The centre of gravity of a body is supported, as long as a line drawn

vertically from that point (the line of direction) falls within the base, *i. e.* the surface with which the body touches the ground.

An inclined stone or beam of wood, in which, as at fig. 39, the vertical line drawn from the centre of gravity falls within the base, cannot fall. If, however, it had the size marked out by the dotted lines, the centre of gravity would be situated at *b*, and the mass must necessarily fall.



39.

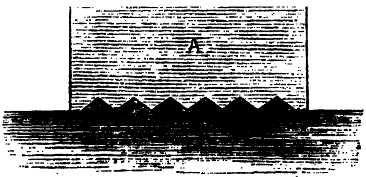
The larger the base of a body, and the nearer its principal mass is to the base, the firmer the body will stand. It is probable that the Egyptians chose the form of the pyramid on this account for their stupendous structures, which have stood for thousands of years.

The bodies of men and animals, the different parts of which are moveable, are continually altering the position of their centre of gravity. A man carrying a load on his back will lean forwards; if he has it in his right hand, he will stretch out the left arm; and any person who is in danger of falling on one side will instinctively endeavour to save himself by stretching out his arm in the opposite direction.

Friction.

64. A great impediment to motion is *Friction*. It arises from the circumstance that no body exists with a perfectly plane surface. If the smoothest substances, such as polished steel, be examined under the microscope, their surfaces will be found to consist of elevations and depressions.

Therefore, in propelling one body along the surface of another, the elevations on the one must be continually lifted over the inequalities on the surface of the other, as is shown in fig. 40. The smaller these elevations are, that is, the smoother the surface, the less friction will there be. In fluids the friction is comparatively slight, the particles being easily displaced. The friction between two bodies may be considerably diminished by filling the cavities on their surfaces with fluids, such as oil or fat, or with very fine powders, such as graphite. Hence these substances are employed for smearing axletrees and various parts of machinery.



40.

The amount of friction is, moreover, dependent upon the weight of the body to be moved. The greater the weight the stronger the friction. The extent of the rubbing surfaces exercises no influence, since to move, for example, 100 lbs. of iron upon a surface of metal a force of 27·7 lbs. is required, whether the mass of iron be in the form of a flat plate or of a square block.

Mechanics.

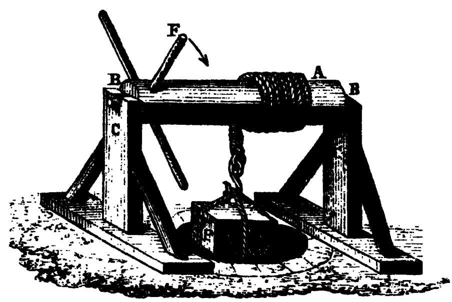
65. *Mechanics* is the science which treats of *forces* and of *motion*. It is the province of the practical engineer to produce any motion that may be required at the least expense of power. He accomplishes this by suitable instruments, which are called *machines*. It is not the object of the present work to exhaust the wide field of mechanical appliances. It seems, however, desirable to pay some attention to those instruments which have become of so much importance.

66. A distinction is made between *simple* and *compound* machines. With the first we have already become, in some measure, acquainted; such, for example, are the lever, the inclined plane, the pulley, and its different forms, and all our common working tools; and in the section devoted to Anatomy, we shall find that most of the motions of the limbs are effected in accordance with the laws of the lever.

Compound machines are produced by the co-operative action of several simple machines, and however difficult it may, at first sight, appear to understand them, they may, nevertheless, all be traced back to the simple machines above alluded to.

67. The *wheel* and *axle* is a simple machine, very frequently employed: it consists of a cylinder, called an *axle*, furnished with pivots at both ends, which in the case of the horizontal axle rest in a groove, and in the vertical axle in holes, so that the axle may rotate round its longer axis. A wheel is connected with the axle in such a manner that its centre lies in the axis of the cylinder, and that the axle must rotate as soon as the wheel is set in motion, and *vice versâ.*

The windlass (fig. 41) furnishes an example of the application of this principle. It consists of a cylinder or axle A, the pivots of which B B rest in notches at the top of the supports C C; the weight P is suspended by a rope coiled round the axle, and the latter is made to rotate by forces applied to the levers. It will be readily seen that two forces P and F endeavour here to turn the cylinder in opposite directions, but that the force F acts on the longer arm of the lever, and the weight P on the shorter arm. The force F may, therefore, be smaller than the weight P, in proportion to the diameter of the axle and the length of the lever B F, to maintain the latter in equilibrium. The levers which move the axle act consequently more effectually the greater their length in relation to the diameter of the axle.



41.

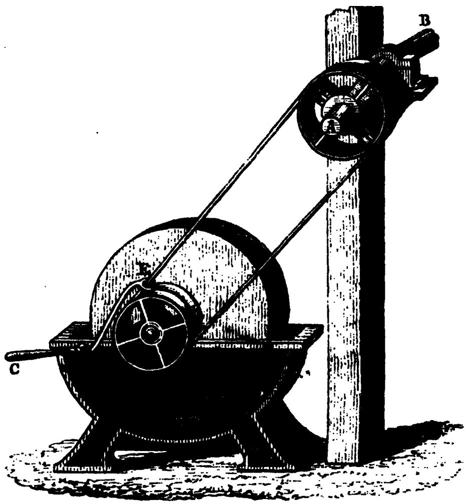
68. *Transmission of Motion.*—According to the nature of the machine, we distinguish three principal parts, namely: the first, on which the motive power acts; the second, on which the resistance to be overcome is exercised; and

lastly, the part between these two which is the means of transmitting the force. In simple machines, for example, the crow-bar, these various parts consist generally of one piece, and are in close proximity.

But in compound machines a considerable number of intermediate contrivances are necessary to transmit the power to the actual working parts, as, for instance, from the water-wheel of a mill to the grinding-stones. In order to transmit the motion, transmission axles, endless bands, and toothed wheels are generally employed.

69. If we enter a cotton factory, we witness on the right and the left of the passages of the long rooms series of machines in full activity, but we do not see the parts which are acted on directly by the moving power. If, however, we look towards the ceiling of the room, we perceive a rotating axle, extending along its entire length, entering by an opening in the wall, and also frequently passing into the adjoining room to transmit the power to other machines. The mules are united to this transmission axle by suitable contrivances,—motion being imparted to the axle either by a water-wheel or steam-engine.

70. The *endless band* is employed when motion is to be transmitted from one rotating axle to another in the same plane, but at some distance from it, as, for instance, from the above-mentioned transmission-axle to the mules. For this purpose there are fastened on different parts of the axle *rollers*, called also drums, which rotate with the axle, and have on their circumference a rope or leather band, the ends of which are united. One of these bands passes over a corresponding roller on one of the mules and sets the latter in motion. Fig. 42 represents an axle A B, which communicates motion to a grindstone. If it be desired to arrest the motion, the band is transferred to an adjoining loose roller by means of the lever C D E. The loose roller is not connected with the axis of the grindstone, but is merely moveable round it, so that this roller, only, rotates while the grindstone remains at rest. Such an arrangement is called a live and dead pulley.



42.

The endless band is either open, as at fig. 42, or it is crossed, as in the common spinning-wheel, or in the centrifugal machine, fig. 23. In reference to the action of the endless band, it must be remarked that the part of the band which is called the driving-side, has a greater tension than the other, since no rotation could be produced if the tension were equally distributed throughout the whole of the band.

If the diameters of the two wheels A and B, over which the endless band

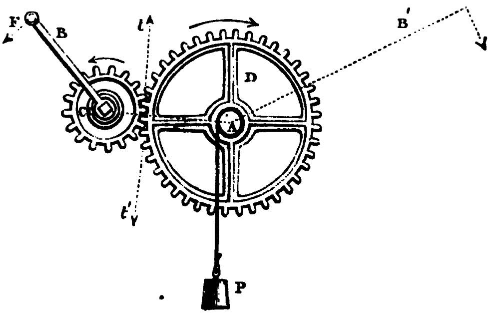
passes, are equal, and A is set in motion, it imparts to B the same velocity of rotation. But if the wheel A which is set in motion be larger than the second wheel B, it will impart to the latter a greater velocity in the ratio of the diameters of the wheels; so that in this manner an exceedingly great velocity of rotation may be produced, for instance, as in the bobbin on the spinning-jenny, the centrifugal machine, &c.

If we conceive the idea of two wheels A and B, connected by an endless band, and a given force acting by a winch on the smaller wheel A, the diameter of which may be $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{n}$th of that of the second wheel B, this power produces the same effect as if the force were acting directly on the axle of the larger wheel B by a winch of the 2, 3, 4, or n-times the length.

71. The *wheel-works* so much employed in mechanics consist of *toothed wheels*, which transmit the motion from one axle to another, which is either parallel to the first or forms with it an angle. On their circumference are alternate teeth and spaces, which accurately correspond and fit in each other in such a manner that one wheel cannot be moved without turning the other in the opposite direction.

The remarks we have made in reference to endless bands apply also to toothed wheels, inasmuch as wheels of equal diameter transfer the motion unchanged from one axle to another; but if the first wheel be of larger size, it imparts to the second a velocity as many times greater as the number of its teeth exceed those of the latter. The second wheel is capable of imparting motion to a third, and this to a fourth, and so on, of continually decreasing size, and in this manner we may obtain any convenient, and if requisite, extraordinary velocity.

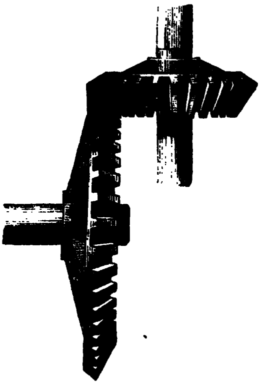
It is also to be remarked that if a given force F acts on the axle of a smaller wheel C by the winch B (fig. 43), and the diameter of the smaller wheel C is, as here represented, one-third, or $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{n}$th of that of the larger wheel D, the force F exercises the same action as if it acted directly on the axle A of the larger wheel D by a lever-arm B′ of 3, 4, 5, or n-times the length. But as winches of such length are very inconvenient, or scarcely manageable, a combination of several toothed wheels are employed with advantage. The smallest wheel which is directly set in motion is called a *pinion* C (fig. 43). It will readily be seen that the motion produced takes place in a reversed sense if the motion be transferred from a larger to a smaller toothed wheel, and that the effect of wheel-works is considerably impaired by friction.



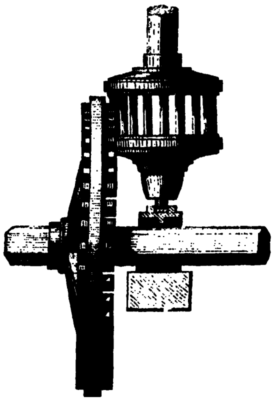
43.

72. The *bevelled-wheel* (fig. 44), and the crown-wheel (fig. 45), transfer the motion from a horizontal to a vertical axis, or *vice versâ*, and the remarks we have made in reference to toothed wheels generally are in every respect applicable to these wheels.

73. The disturbances arising to a machine from the irregular action of the



44.



45.

moving power would render the generality of operations impossible if no means were adopted to counterbalance these disturbing influences.

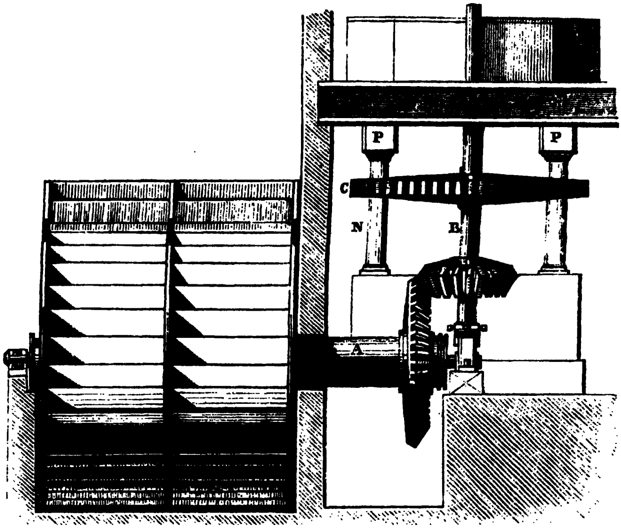
To accomplish this a large heavy wheel of cast-iron, called a *fly-wheel*, is fixed to the axle, and rotates with it. If a sudden increase of force takes place, this excess of power acts also on the heavy fly-wheel, and the effect of the increase of power on the whole arrangement is rendered less perceptible; if, on the other hand, the moving power be decreased or even temporarily interrupted, the motion of the whole of the machinery is thus only slightly diminished, since, according to the laws of inertia (§ 39), the fly-wheel retains, at least for a short time, its velocity, and keeps the rest of the machinery in motion until the moving power again acts in a suitable manner. Fly-wheels are employed in rolling mills, mints, in stationary steam-engines, watches, and in grinding machines.

74. Amongst the numberless mechanical arrangements employed for the most varied purposes, there are two which we consider as especially worthy of a more minute description, since their applications are intimately connected with our most necessary wants; these are the *flour-mill* and the *clock*. A knowledge of their construction appears as attractive as it is useful.

The Flour-Mill.

75. Most of our flour-mills are moved by water power. The water either exerts its force on the float-boards, which are situated on the under part of the wheel (*undershot-wheel*), or it flows into the buckets at half the height of the wheel (*breast-wheel*), or else it is conducted in a channel over the wheel and falls into similar buckets on the front, in which case the wheel is called an *overshot-wheel*. In the undershot-wheel the water acts by its velocity, and in the breast-wheel it produces rotation by its weight and force, whilst in the overshot-wheel it acts chiefly by its weight. The adoption of either of these wheels depends on the quantity and on the fall of the water at command.

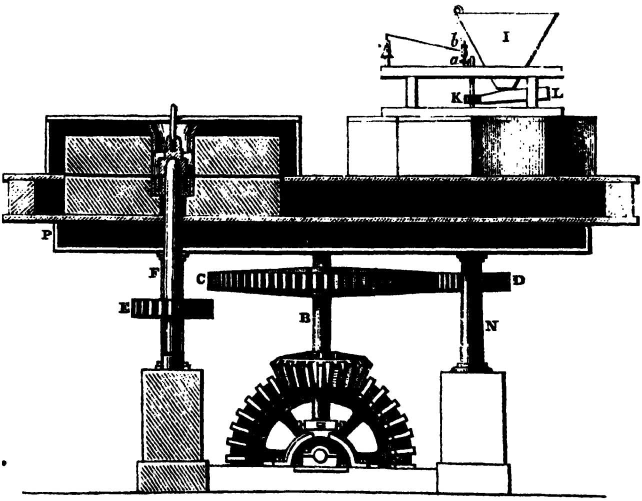
In fig. 46 we have given a representation of an overshot-wheel which turns



46.

the axle A. This axle extends to the mill, and by means of two bevelled wheels transfers its rotatory motion to the vertical axle B.

In fig. 47 the wheel C is employed to turn two pairs of millstones, of the



47.

first of which we have given a sectional and of the second a front view. For

this purpose two toothed wheels E and D are moveable on the vertical axles F and N, and may be regulated in such a manner as to work into the crown-wheel C, and in this case the stones are set in motion. In the figure the stones on the right are supposed to be in motion, whilst those on the left hand are at rest. From the latter we will pursue the interior arrangement. The axle F rests below by a peg in a groove, and passes above through the floor P and through the millstone which rests upon it, and which is called the *under-stone*. On its upper conical end this axle carries the second millstone, called the *runner*, which is fastened to it by the mill-iron, and is, therefore, turned round with the axle. Between the two millstones only a very small space intervenes, and it is of the greatest importance that the runner rests exactly on its centre of gravity, in order to preserve a uniform distance on all sides.

The hole in the centre of the runner is not perfectly closed by the mill-iron, but there are some openings left which allow the corn to fall down between the stones, where it is ground into flour and bran by the rotation of the runner. In order perfectly to crush the grain, shallow furrows are cut in the opposite surfaces of the stones, and act in a similar manner to the blades of a pair of scissors. By the centrifugal motion the ground corn is removed from between the two stones to a room closed on all sides, and thence carried through an aperture to the bolting apparatus. This arrangement, which serves to separate the flour from the bran, is not represented in the figure; it is set in motion by a prolongation of the axle B.

The corn which is to be ground is introduced into a funnel-shaped box I, called a *hopper*, the lower opening of which is nearly closed by a little inclined-box L, called the *shoe*. On a prolongation of the axle which supports the runner are several pegs K, which, in turning, repeatedly shake the shoe, so that the corn gradually slides down and falls into the aperture of the runner.

A bell C is made to ring, to inform the miller when the hopper is nearly empty. A string passes from the bell to the peg *b*, and thence over a pulley into the hopper. To the end of the string is attached a large but light piece of wood, which on filling the hopper is buried by the miller beneath the corn, so that the peg *b* is at such a height that it cannot be touched by the peg *a* during the rotation. The quantity of corn, however, soon becomes so small that it is no longer sufficient to retain the piece of wood in the same position, and the peg *b* descends so far that the peg *a* causes the bell to ring by touching *b* at each rotation.

The diameter of a millstone is generally about 4 feet, the runner makes about 70 rotations in a minute, and a pair of millstones grind in 24 hours from 500 lbs. to 600 lbs. of corn.

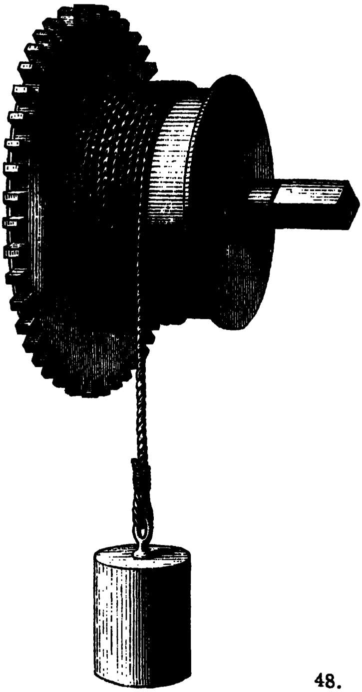
The Clock.

76. If we succeed in imparting to an object a perfectly uniform motion, so that it describes an equal distance in the same time, the motion may be employed as a measure of time, and it is this which we expect of a good clock. This problem would be easily solved if we had at command a force acting with perfect uniformity. This, however, is by no means the case, since the descending *weight*, as well as the *spring*, which are employed most advantageously to set our clocks in motion, exert an action which is unequal.

If the cord (fig. 48) to which a weight is suspended be wound on a cylinder fur-

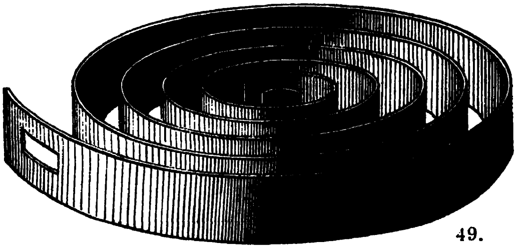
nished with a toothed wheel to transmit the motion, the cylinder is set in rotation by the descending weight slowly at first, but soon increasing, because the weight, as a falling body (§ 26), quickly acquires an accelerated velocity.

We may employ for the same purpose a *spring* (fig. 49), of highly-elastic steel, which is fastened by its external extremity to a fixed point, and by its inner end to an axis which is capable of rotating round itself.* If the spring be now wound up and left to itself, it must, by virtue of its elasticity, cause the axis to rotate in an opposite direction (fig. 50). In the first moment, when the spring is strongly contracted, the rotation is very rapid; it soon, however, becomes slower, and finally ceases when the spring has regained its original form. Toothed wheels, which are thus set in motion by weights and springs, would attain a motion much too irregular to cause the hand on the dial, which is set in motion, to traverse over equal spaces every hour.

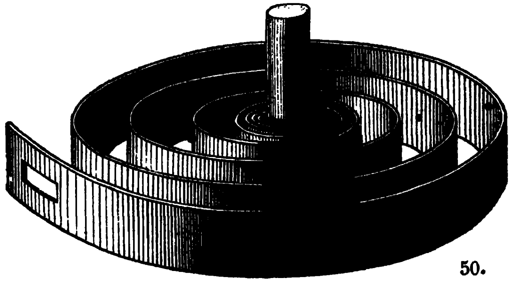


48.

77. If, however, we check the unwinding of the cord, which is caused by the descending weight, by means of a regular resistance acting at very short intervals, it is evident that the weight cannot attain an accelerated velocity, consequently the cord is unrolled slowly and regularly, and imparts to the cylinder on which it is fastened, and also to the works connected with it, a corresponding movement. If, moreover, a wound-up spring be fastened by means of its axis to a combination of wheels, which



49.



50.

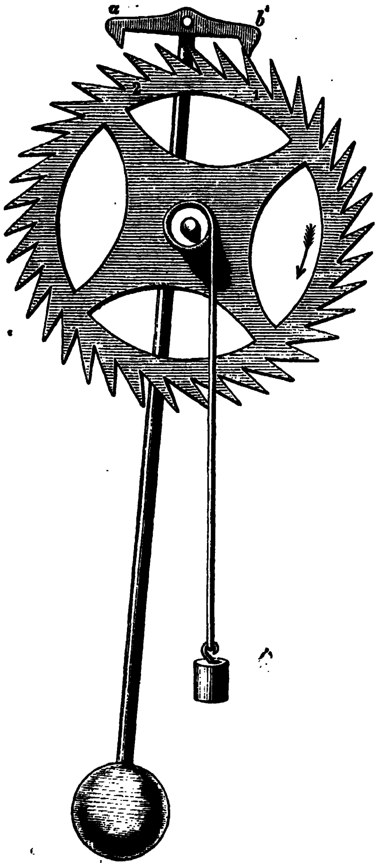
* This is the arrangement adopted in Geneva watches. Fig. 52 represents the English construction.—ED.

likewise receives a transient check at very short intervals, the spring cannot be relaxed suddenly, but its force will be divided over a longer space of time.

These facts led to the use of such an arrangement, called an *escapement*, being adopted in all our clocks.

The escapement movement is most perfectly accomplished by the aid of the pendulum, since, as we have seen in § 27, that within a certain limit described by the pendulum all its oscillations are of equal duration.

Fig. 51 represents a toothed wheel connected with the axis, on which the weight acts, and above it is suspended a pendulum, the upper part of which, called the *beam*, is furnished with pallets *a* and *b*, for the purpose of catching the teeth of the wheel. It will be readily seen that when the pendulum is set in motion, its pallets on the right and left alternately drop in the teeth of the wheel, and must produce a short and transitory interruption, thus transforming the accelerating velocity of the falling weight into a uniform velocity. If the beam have a horizontal position, both teeth would simultaneously drop and entirely interrupt the rotation of the toothed wheel; hence it is that we may entirely stop a pendulum clock by holding the pendulum for some seconds in a vertical position, and again set it in motion by moving it gently on one side.

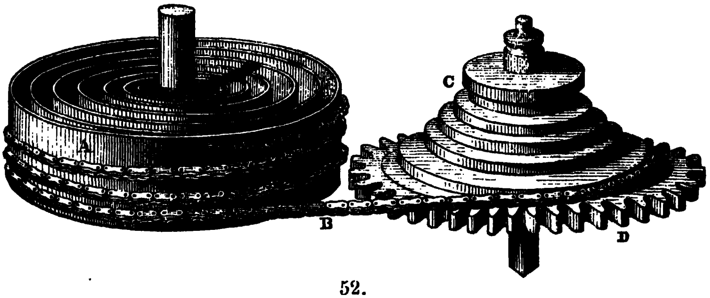


51.

78. Greater difficulties are presented in the regulation of a watch, since a pendulum cannot, of course, be employed. It was originally endeavoured to compensate the action of the spring by means of the *fusee* (fig. 52), an arrangement which is frequently seen in English watches.

The conical-wheel (fusee) D, which has on the upper part a spiral plane, is turned round by the watch-key. By means of a linked chain this wheel is connected with the barrel A, on which the chain is fastened and wound. To the inner side of the barrel one end of the spring is fastened, and its other end is held by an immovable pin. In winding up the watch the chain from the barrel is wound upon the circumference of the fusee, the box-wheel makes several rotations and contracts the spring, which, as soon as the works are left to themselves, again opens and causes the barrel A to rotate in an opposite direction. In this rotation the barrel imparts, by means of the chain, a motion to the fusee, the teeth of which set

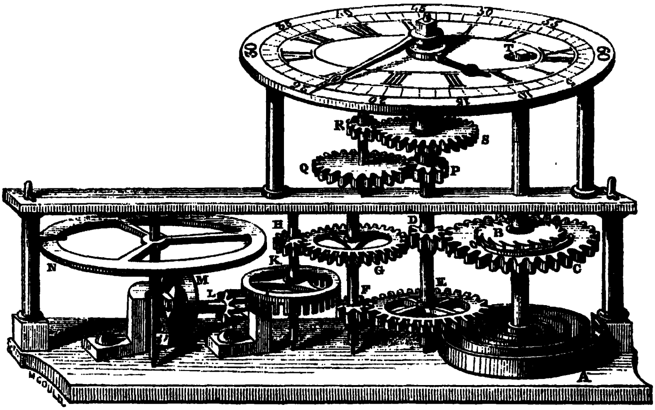
the whole of the works in motion. Immediately after the watch is wound up, and the spring most strongly contracted, it acts by means of the chain on the highest plane of the fusee, which is of the smallest diameter, and in the same



52.

degree as the spring is unrolled and its tension relaxed, the planes increase in size, so that the continually-decreasing force acts on a continually-increasing lever arm. In this manner the inequality of the motion receives a suitable compensation.

The arrangement just described, however, is insufficient to produce a perfect regulation, and is entirely omitted in watches furnished with the improved escapement, as may be seen in the following figure, which represents the entire



53.

works of a watch, and in which all the axes furnished with wheels are made longer than they are in reality for the sake of greater perspicuity.* It should be mentioned that the wheels P Q R S form the hand-work, and all the other the working train of the watch.

By means of the winding square T, the spring A is contracted, or, in other words, the watch is *wound up*, when the elasticity of the spring causes its own

* The arrangement with regard to the spring (fig. 53) is that of modern Geneva watches, while the escapement is the old vertical escapement of ordinary English watches.—Ed.

axis to rotate in an oppôsite direction, as well as the toothed-wheel C, which is fastened upon it, and which is called the *great wheel.*

The great wheel catches first in the pinion D, and in this manner moves the hand-works. The tension of the spring and the action of the escapement, to be described hereafter, should be regulated in such a manner that the axis of the small wheel P, which is called the *minute-wheel*, turns round once in an hour. On the end of this axis and on the surface of the dial the minute-hand is fastened, which in twelve hours describes the same number of rotations. The hour-hand, however, must only make one rotation in an hour. It should first be observed that the axis of the hour-hand is in the form of a hollow tube, moveable round the axis of the minute-hand, and has fastened to its extremity the wheel S. Let us now see in what manner the twelve rotations of the minute-wheel P are, by means of toothed-wheels (§ 71), converted into one rotation of the hour-wheel S. For this purpose the minute-wheel is furnished with eight teeth, and catches in the other wheel Q, which has twenty-four teeth; hence the axis of the latter, together with the pinion R which is fastened to it, makes only *three* rotations in twelve hours.

The pinion R has eight teeth, which catch in the thirty-two teeth on the hour-wheel S, which, consequently, turns round only once, whilst R makes four rotations and the minute-wheel twelve.

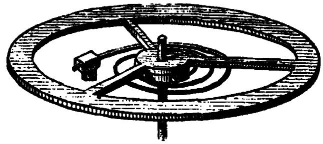
If we now consider the entire works, we observe that the movement is propagated and the contrate-wheel K set in rotation by means of the *intermediate wheel* E, the pinion F, the third wheel G, the pinion H; the contrate-wheel K imparts its motion, by means of pinion L, to a horizontal axis, with its peculiarly toothed escapement-wheel M. In thé front of the escapement-wheel we observe a vertical axis, called the *verge*, which carries on its upper part a fly-wheel N, which is also called a *balance-wheel* (§ 73), whilst lower down there are two little plates of steel or pallets, *i i'*, the mutual distance of which is equal to the diameter of the escapement-wheel M, and which in reference to their position with the verge are at right angles to each other. The last-mentioned parts form, with the escapement-wheel, the *escapement* of the watch.

If a tooth on the upper part of the escapement-wheel M meet the upper pallet *i*, it imparts to the latter a slight backward motion; but immediately afterwards the other pallet *i'* meets with an under tooth of M, and is driven by it forwards, so that as long as the escapement-wheel is in motion the pallets *i i'* are alternately driven backwards and forwards. It will be readily seen that in this manner the spindle, together with the balance-wheel, receive a corresponding alternate rotation, describing an arc of a circle. But as often as a pallet comes in contact with a tooth of the escapement-wheel, it receives a backward push from the balance, since this does not lose the whole of its velocity by the encounter, by which means the balance-wheel is somewhat retarded.

If the above-described oscillations of the balance-wheel were, like those of the pendulum, of equal duration, the resulting retardations would also be of equal duration, and the movements of the watch would be regular. This, however, is not the case, because the spring itself is the moving power which primarily causes the oscillations of the balance and keeps it perpetually in motion, so that the inequalities of the moving force are propagated to the balance.

If we employ on the balance another very small spring, these irregularities receive an important compensation. Such a contrivance, which is also termed a

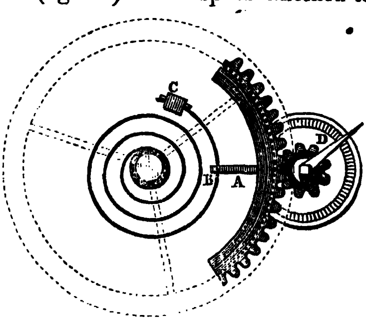
balance or *pendulum-spring*, may, like the pendulum, be set in oscillations of almost equal duration by a slight blow, with this difference, however, that in the former they take place in a vertical and in the latter in a horizontal plane, and that with the former the oscillations are maintained by gravitation, and in the latter case by the elasticity of the spring. In this manner it has been possible to produce a regular escapement in the movements of the watch, which attained to the greatest exactness since the adoption of the balance-spring.



54.

Since, according to what has been stated, the watch is regulated by the oscillations of the balance, these must be of certain duration. The watch would go too fast if the oscillations were too quick, and in the opposite case, too slow; we must, therefore, adopt a means of imparting to the oscillations of the balance-wheel the required duration. This is done by making the spring shorter or longer, according to circumstances, since it is easily to be seen that its tension will be increased by shortening and decreased by lengthening, and in the same proportion the number of oscillations within a certain time will increase or decrease.

Such a contrivance is called the *regulator* (fig. 55). The spiral fastened to the stud C is inserted at B in a groove of the arm A, which is made in one piece with the toothed circular section. The result of this is, that only from the point B the elasticity of the spiral exerts its influence. If now the hand D is moved in either the one or the other direction, a corresponding motion of the arm A is produced by the catching of the teeth, the stationary portion B C of the spiral becomes shortened or lengthened, and in this manner the oscillations are made of the required duration.



55.

79. Cylinder watches are distinguished from the above-described lever watches, by the escapement in the latter being performed by the vertical wheel M (fig. 53), whilst in the cylinder watches the teeth of a horizontal wheel catch in the hollow and peculiarly-cut axis of the balance, which is called a *cylinder*. This arrangement has the advantage that the cylinder watches can be made very flat, becoming thereby more convenient to carry, and which may be recognised even by their exterior.

80. Regarding the history of clocks, it may be remarked that wheel clock-work was unknown to the ancients, and in reference to the time and by whom the discovery was first made much uncertainty prevails. Artificial wheel-works, especially those employed for astronomical purposes, were first found in convents, and in these also the first clocks moved by weights might have existed.

The discovery of the watch is generally ascribed to *Peter Hele* in 1500, and his watches, in consequence of their shape, were called Nuremberg eggs.

On the other hand, it is certain that the requisite exactness in the going of *clocks was first attained by the distinguished* Dutch philosopher *Huygens* in 1657, who first carried out the idea of employing the pendulum and the spiral to the regulation of time-pieces.

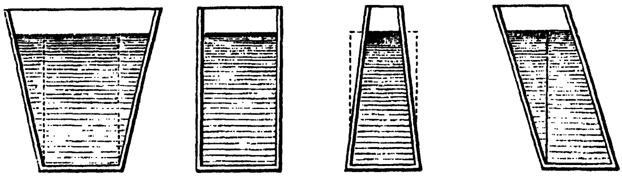
Equilibrium of Fluids (Hydrostatics).

81. A fluid is in a state of equilibrium when all the particles on its surface are equidistant from the centre of the earth. Hence the surface of a fluid in a state of rest must have the form of the segment of a globe. This is really the case, as may be observed with large masses of water,—for instance, the surface of the sea. Smaller surfaces of fluids appear, however, when in equilibrium, as perfect planes at right angles with the direction of gravity.

If a higher position be given to one portion of a liquid than to another, the consequence of the slight disarrangement of the particles is a continuous motion, until the state of equilibrium is re-established. The flowing of rivers towards the sea is owing to the tendency of the water on the surface of the earth to maintain itself in equilibrium.

As a consequence of the ratio of equilibrium in fluids, the surfaces of liquids, contained in vessels having one part wider than the other, or in different vessels in communication, invariably stand at equal heights from the bases of the vessels. Thus in watering-pots, tea-pots, or oil-lamps, the liquid is always found to stand as high in the narrow spouts as it does in the wider portions of the vessels. If a stream of water be conducted from a height to a plane, the reservoir will form, as it were, a vessel connected with the spring by the conducting pipes, and the water will attain a similar height in both parts. This phenomenon familiarly explains the formation of *fountains*. The *sides* of vessels containing liquids also suffer a pressure, which for equal parts of the walls is the greater the nearer these parts are situated to the bottoms of the vessels. That this pressure may be employed as a motive power may be shown by suitable arrangements, as in Segner's wheel and in the *turbine*.

82. The amount of pressure sustained by the bottom of a vessel filled with a liquid, does not depend on the amount of liquid, but upon its height in the vessel and the extent of the vessel's base. It may be proved by decisive experiments that if the heights and the bases of different vessels are equal, as is the case with those represented by figs. 56, 57, 58, and 59, the pressure sus-



56. 57. 58. 59.

tained by the bottoms of the vessels will be in all cases perfectly equal, although the amount of liquid they contain varies to a considerable extent, as shown by

the figures. A very great pressure may, therefore, be obtained with a very small amount of liquid, if it be poured into a very narrow and high tube, widening considerably towards the base. The amount of pressure obtained is the same as if the tube were of equal width the whole way up.

If a cubic inch of water weighs $\frac{1}{2}$ oz., the base of the vessel measures 32 square inches, and the height of the liquid 1 inch, the base sustains a pressure of 1×32 cubic inches, equal therefore to 1 lb. of water.

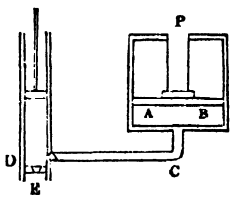
Assuming the height of the column of liquid to be 100 inches, the pressure sustained by the base is 100×32 cubic inches, or 100 lbs. of water.

83. If one portion of the surface of a liquid be exposed to a certain pressure, the pressure becomes equally dispersed in all directions.

In illustration of this, a vessel, closed on all sides, is provided with two openings, each a square inch in diameter, one at the top and another at the side. The latter opening is closed with a cork: the vessel is then filled completely with water, and the liquid is pressed upon, by a piston through the upper opening, with a force equal to 100 lbs. Every portion of the sides of the vessels, measuring 1 square inch, has now to bear 100 lbs. pressure. If the surface of the vessel is 60 square inches, the total pressure on its sides will amount to $60 \times 100 = 6{,}000$ lbs. The cork in the lateral opening has to bear a pressure of 100 lbs. If it cannot withstand this, it is of course forced out. Supposing the lateral opening to be 2 square inches in size and to be closed by a plate, the latter must be pressed against the opening from the outside with a force of 200 lbs., in order to counterbalance the inward pressure.

84. The hydraulic press is constructed upon the above principles.

In fig. 60 A B represents the bottom of a hollow cylinder, into which is fitted the piston P: into the bottom of this cylinder there is introduced a pipe C leading from the forcing pump D; water is supplied to this pump by a cistern below from which is led the pipe E, furnished with a valve opening upwards at the point where it is joined to the pump-barrel. Where the pipe C enters into the pump-barrel there is also a valve opening outwards into the pipe; consequently when the piston D rises this valve shuts, the valve of the cistern-pipe opens, and the fluid rises into the pump-barrel. When the piston begins to descend, the cistern-valve closes, and the water

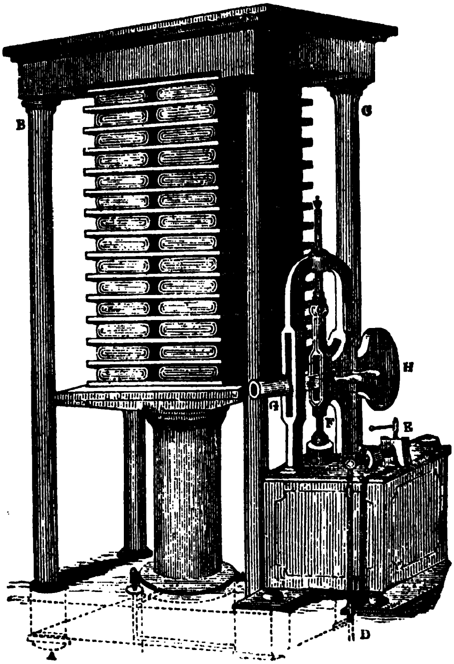


60.

is forced through the pipe C into the large cylinder A B; and by the law of fluids above alluded to, whatever pressure may be exerted by the piston D on the surface of the water in the pump will be repeated on the piston of the large cylinder A B, as many times as the area of the small piston D is contained in the area of the large piston A B; that is, if the area of the pump-piston were 1 square inch, and that of the cylinder 100 inches, and if the piston were forced down with a pressure of 10 lbs., then the whole pressure on the bottom of the piston A B would be $10 \times 100 = 1{,}000$ lbs.

Fig. 61 gives a correct idea of the most improved construction of the press. A B C D is a strong iron frame, at one side of which is the cistern containing the water for the supply of the force-pump F, worked by means of a lever, which fits into the tube G; at the other end of the tube is the counterpoise H. The water is forced, in the manner above described, into the bottom of the

large cylinder, and the piston being pressed upwards, the board supporting the materials is raised, and the objects are compressed between the board and the top of the press. To prevent the machine from bursting, a safety-valve, capable of overcoming a given pressure, is employed, and for the purpose of admitting the water, or drawing it from the large cylinder, the press is furnished with the stop-cock E. From the facility of operating with this machine, and its great power, it is now applied to many purposes.



61.

85. Let us picture to ourselves, in a vessel filled with a liquid in a state of perfect equilibrium, a certain portion of this liquid, situated in the centre of the whole, and submit it to a closer examination. The dark part h', in fig. 62, may be considered to represent this portion. Now, it would certainly not occupy the position that it does, if it were not maintained there by the pressure exerted on all sides by the remaining liquid. It is evidently pressed downwards by the upper portion of the fluid, but, as it does not sink, the liquid situated below it must necessarily exert an equal upward pressure. It is retained equally in equilibrium by the portions of liquid pressing at the sides. The portion h' is, therefore, kept in perfect equilibrium by the liquid surrounding it; its tendency to sink, by the force of its gravity, being counteracted by the pressure from below. If it were possible to suspend it by a thread to the beam of a balance, the equilibrium of the latter would be as little disturbed as if it were connected by a thread to a weight lying upon, and therefore supported by, a table.

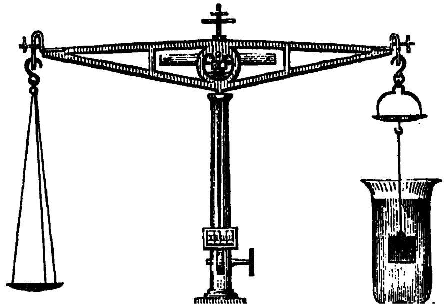
62.

If this portion h' of the liquid were replaced by another body of equal weight and volume, this would obviously bear the same relation to the surrounding liquid, and would be, therefore, just as completely supported.

Suppose the body immersed to have the same volume, but to be lighter or heavier than the liquid displaced—even then, the pressure exerted by the surrounding liquid is the same in every case: if the body is lighter than the water displaced, it will not retain its equilibrium, and will, therefore, rise to the surface; but if it is heavier, the surrounding liquid will certainly counterbalance a portion of its weight, but not the whole, and the body will consequently sink to the bottom.

86. The following law was established by Archimedes: *If a body be immersed in a fluid, a portion of its weight will be sustained by the fluid, equal to the weight of the fluid displaced.*

A few common examples will serve as proofs of this theorem. A pail filled with water may be lifted about with ease as long as it is immersed in water, its whole weight being supported by the latter. But if the pail be taken out of the water, an amount of force, equal to its entire weight, will be required to lift it. In the same manner a man may be lifted and moved about in the water with the force of one finger.



63.

87. One cubic inch of water weighs about half an ounce (more exactly, 252½ grains). Any other substance, for instance, a piece of lead, is weighed first in air, as usual, and found to weigh 11 ozs. If it is then weighed while immersed in water, as shown at fig. 63, the latter will be found to support about 1 oz. of its weight. This experiment shows that 11 ozs. of lead occupy the same space as 1 oz. of water (or nearly 2 cubic inches). From this we conclude, that lead is eleven times heavier than water.

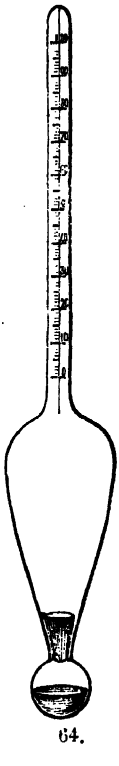
This is the method generally adopted for determining the density or specific gravity of bodies.

88. It may be easily conceived that the heavier a fluid is, the greater will be the weight, of a body immersed therein, that it is capable of supporting.

According to the table, § 34, the relations of the densities of alcohol, water, and sulphuric acid, are expressed by the figures $0{\cdot}79 : 1 : 1{\cdot}85$.

A glass tube, similar in shape to that represented by fig. 64, which is loaded at the bottom with a little mercury or a few shot, to give it a vertical position when immersed, will evidently not sink to an equal depth in all three of these liquids. If it sinks to half its length when immersed in water, it will sink still lower in alcohol, that liquid being lighter than the former, while in sulphuric acid, which is so much heavier than water, it will not sink nearly so deep.

These instruments, which are termed *hydrometers*, are particularly adapted for comparing the densities of different fluids: they are employed under various names, according to the purposes to which they are applied.



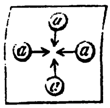
64.

Equilibrium of Gases.

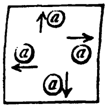
89. We have become acquainted, at §§ 8 and 17, with the properties by which aeriform bodies or gases are so easily distinguished from fluids and solids.

In our examination of these properties we shall, for our examples, generally select the air that surrounds us, as everything that may be remarked as to its general properties holds good equally with the other gases.

The particles of air are maintained at such a distance by heat, that their mutual attraction appears to cease altogether. The particles *a a a a* (fig. 65), existing within a certain space, do not appear to have any tendency to approach in the direction denoted by the arrows, on the contrary they exhibit an inclination to increase the distance between each other, by moving in the course shown by the arrows in fig. 66.



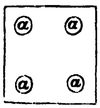
65.



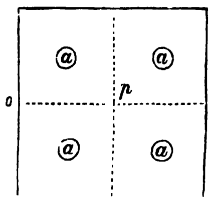
66.

Gases are, therefore, considered to be bodies, the particles of which exhibit a tendency to move away from each other continually: this property is ascribed to the action of a peculiar kind of force, termed *repulsion*.

, 90. We will now see what deductions may be made from this property of gaseous bodies. If the same space of air be assumed as enclosed in a vessel (fig. 67), the particles *a*, possessing the tendency to move away from each other, will exert a pressure on the sides of the vessel.



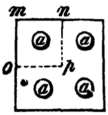
67.



68.

This expansive property of gases is called their *elasticity*, or *tension*.

If we imagine the vessel (fig. 67) expansible to four times its size, by a peculiar construction of its sides, as shown in fig. 68, the particles *a* will in consequence move to a greater distance from each other. While, therefore, the sides of the vessel (fig. 67) had to sustain a pressure of 4 *a*, a portion of the vessel (fig. 68), marked *m n o p*, equal in size to the former vessel, has to withstand only one-fourth of that pressure, or 1 *a*.



69. 70.

On reversing this experiment, by compressing the air as in fig. 69 to such an extent that it occupies only one-fourth of its original space (fig. 70), it is evident that the sides of the vessel (fig. 70) will have to sustain a pressure of 4 *a*, while a portion of the vessel, *m n o p* (fig. 69), equal in size to the former, will have to sustain only a fourth part of that pressure, or 1 *a*.

91. In the foregoing examples we had the same quantity of air existing in different states of expansion and elasticity; and we saw clearly that its elasticity decreases with increasing expansion, whilst, on the other hand, it gains in elasticity when compressed into a smaller space.

This relation between expansion and elasticity obeys a certain law, which

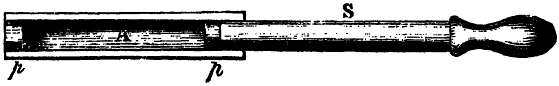
may be expressed thus: *the elasticity of a gas stands in inverse ratio to the space it occupies.*

With the same amount of air, therefore—

Occupying the space of	1	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	.	.	.	.	$\frac{1}{100}$	$\frac{1}{n}$
The tension is . .	1	2	3	4	5	6	.	.	.	.	100	n

92. Hence, by compressing air into a very small space, by means of proper apparatus, we can increase its tension to such an extent as to apply it to the production of powerful effects.

The *air-gun* is an example of the application of this power, but a still more familiar one is the *pop-gun*, a well-known toy (fig. 71). The space A is en-



71.

closed by the two stoppers p p. On the stopper p nearest to the piston being pushed farther into the cylinder by the rod S, the air contained in the space A is compressed until its tension becomes so great as to drive out the stopper at the mouth of the cylinder with great force, accompanied by a report. The stopper p may be considered as a moveable side of the vessel A.

93. The tendency of the particles of gases to repel each other would soon cause the air to be dispersed over the whole universe if it were not influenced and retained by the attractive force of the earth. The latter is, therefore, surrounded by the air, as a kind of covering, which we term *atmosphere*, and which has a height of about 30 or 40 miles.

Another result of the attraction of air by the earth is the pressure which the former exercises upon every substance on which it rests. This pressure may be measured, or, in other words, the weight of the air may be determined.

For this purpose, a hollow glass globe is filled with air and accurately weighed. The air is then removed from the globe by means of the air-pump, and the globe again weighed. The difference between the two results is the weight of the air contained in the globe.

The density of the air has been found, by this method, to be 770 times less than that of water. Supposing the globe with which the experiment is made to contain exactly 1 oz. of air, it would, when filled with water, hold exactly 770 ozs. of the latter; 770 cubic inches of air weigh, therefore, as much as 1 cubic inch of water.

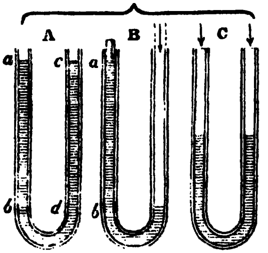
94. We are acquainted with several gases besides atmospheric air which are possessed of different densities: thus, for instance, hydrogen is 14 times lighter than air; the density of chlorine gas is 2½ times, and that of carbonic acid gas 1½ times, greater than air.

The application of gases lighter than air to *aerostatics* will be described hereafter.

95. The pressure exerted by the air may be indicated and determined even without the use of the balance.

The bent glass tube (fig 72, A) is supposed to contain mercury. As we

have seen at § 81, the surfaces of the liquid must be equally high in both arms; hence it is evident that the column of mercury *a b* holds the column *c d* in perfect equilibrium.



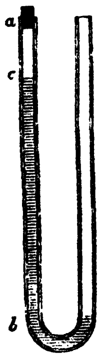
72.

The opening *a* is now closed air-tight by means of a cork, and one-half of the mercury is removed from the tube by inclining and shaking it. The mercury will now be found not to stand equally high in both arms, but to remain in the one arm, as shown at fig. 72, B. What is it that now holds the column of mercury in equilibrium? Evidently nothing else than the column of air pressing into the other arm, and which we may imagine as extending upwards to the confines of the atmosphere.

On removing the cork from the opening *a*, the mercury will immediately fall and stand at an equal height in both arms of the tube, as seen at C. The air, pressing equally on both openings of the tube, once more maintains the equilibrium (comp. § 49).

96. The result of the experiment is slightly different if a glass tube of considerable length is employed, each arm being about 36 inches high. It will be found, on conducting the experiment as above, that the mercury will not remain perfectly stationary in the one arm, but will fall to a certain point *c* (fig. 73). In measuring the height of the column of mercury remaining in the arm, from *b* to *c*, it will be found to be 29·9 inches or 760 millimeters in height.

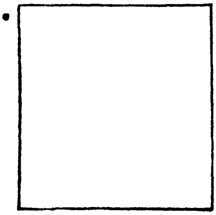
97. This clearly proves that the air cannot maintain in equilibrium a column of mercury of any indefinite height.



73.

Assuming that the tube employed measures 1 square inch in the bore, the two forces that maintain each other in equilibrium are, on the one side, a column of mercury, 1 square inch in thickness and 29·9 inches high, consisting therefore of 29·9 cubic inches of mercury, and, on the other side, a column of air, 1 square inch in thickness, but of the height of the atmosphere.

The weight of the above column of mercury is about 14¾ lbs. (see § 33); a column of air of 1 square inch in thickness, and of the height of the atmosphere, must therefore likewise weigh 14¾ lbs. As the air surrounds the earth and every object thereon, and as the pressure of the atmosphere acts in all directions similar to that of water (comp. § 83), every square inch (fig. 74) of the surface of a body situated in the air has continually to sustain a pressure of 14¾ lbs.

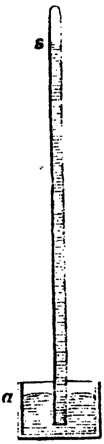

74.

Supposing the surface of a table to measure 1 square meter = 1550 square inches, it would have to sustain a pressure of $1550 \times 14{\cdot}8 = 22{,}940$ lbs.

The surface of the body of a grown person measures about 1 square meter. The atmospheric pressure that such a person has continually to sustain, is, therefore, equal to the enormous weight of 22,940 lbs. We are, however, not in the least sensible of this pressure, as the air, pressing equally on all sides, maintains itself in equilibrium. If the atmospheric pressure could be

suddenly removed from the one side of a man, he would receive a blow on the other side equal to 11,470 lbs., a force which no human strength could withstand.

98. The barometer (fig. 75) is the most simple instrument for measuring the atmospheric pressure. It consists of a glass tube several lines in width and from 36 to 40 inches in height, and sealed at one end. It is filled perfectly with mercury, its open end being closed with the finger, and then, as in fig. 75, immersed in mercury, and again opened. The mercury in the tube will now fall to the point *s*, which is 30 inches above the surface of the mercury in the vessel *a*. This distance is called the *height of the barometer*. In this case also, the column of mercury is evidently maintained in equilibrium by the atmospheric pressure acting upon the surface *a*.



75.

The question now arises, what does that portion of the tube above the column of mercury contain? Nothing but a perfectly *empty space*, which has been named, after the discoverer, the *Torricellian vacuum*.

For a good barometer, the tube employed should not be too narrow; its bore should be at least three or four lines in diameter. The glass and mercury must be perfectly clean and pure, and the vacuum must of course not contain a trace of air, as the latter would exert its tension in overcoming a portion of the atmospheric pressure. In order to prevent the possibility of the presence of any air, the mercury is for some time heated or boiled in the tube, or before it is poured into it.

99. Observation has shown that the mercury in one and the same barometer does not at all times stand at an equal height; hence it follows that the pressure of the atmosphere is not always and everywhere the same.

The variations in the height of the barometer are termed its *rising* and *falling*.

If a barometer stands at 30 inches at the sea-side, and if it be afterwards taken to the top of a mountain, the column of mercury will no longer stand at the same height. The higher the place of observation, the lower will the barometer fall.

This is easily accounted for. The distance from the summit of a mountain to the confines of the atmosphere is evidently less than from the sea-shore. The column of air pressing upon the barometer at a certain height is shorter in proportion to this height, the force of its pressure is, therefore, less.

The barometer is consequently an instrument of the greatest importance for determining altitudes: it may be constructed for travellers so as to be transportable, and has, in this state, already been taken by natural philosophers to the highest summits of the Alps, the Andes, and the Cordilleras.

100. The height of the barometer is, however, influenced by other causes, besides the altitude of the place of observation, which frequently render it subject to certain variations. Severe tempests, which arise from great disturbances in the equilibrium of the air, and earthquakes, are generally preceded by a considerable fall of the barometer.

If the air contains much aqueous vapour, as it generally does in fine and

warm weather, the pressure of the air is increased by the tension of the vapour: at such times the barometer will stand very high.

But when, on the cooling down of the air, the vapours lose their tension, the pressure of the atmosphere will of course decrease, and the barometer will fall. The condensed vapours soon render themselves visible in the form of clouds and rain.

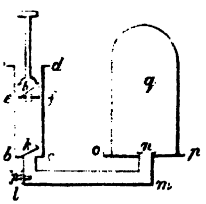
As the barometer indicates these changes long before the clouds and rain make their appearance, it may be considered as a prophet of the weather, and is to be found in that capacity in many houses.

101. The atmosphere is not equally dense at every height. Its density is greatest at the surface of the earth, the lower strata of air having to sustain the pressure of those above.

The decrease of atmospheric pressure is observed to be considerable even on the summits of very high hills. If a bottle, filled with air and well corked, be taken to a great height, the cork will be forced out of the bottle. The blood is driven, by the action of the heart, with a certain force into the finest and most delicate veins in the extremities of the human body, which are, however, capable, under the ordinary pressure, of withstanding this force. At altitudes of 24,000 and 26,000 feet, however, where the atmospheric pressure on the surface of the body is much lessened, these small blood-vessels burst, the blood forcing its way through them. The air at these heights is likewise no longer sufficiently dense for perfect respiration.

102. The tension, or the expansive property, of the air affords us a means of rarifying it in closed vessels, to such an extent that the latter may be almost considered as free from air. The instruments used for this purpose are called *air-pumps*.

Let us examine the construction of such an instrument (fig. 76). The tall cylinder, *a b c d*, is connected by means of a tube with the glass bell *q*, the margin of which fits air-tight upon the disc *o p*, which is called the *plate* of the air-pump. The bell is the space in which the air is to be rarified. For this purpose, the cylinder *a b c d* is provided with a piston fitting air-tight, and perforated in the centre, and with the two valves *h* and *k*, which open when a pressure acts upon them from below, and remain closed in the opposite case.



76.

The piston having been first pushed into the cylinder as far as *b c*, is now drawn upwards. The valve *h* first remains closed, on account of the pressure of the external air, and thus a vacuum in *b c* is produced. But, in consequence of the tension of the air, a portion of that contained in the bell rushes immediately through the opening *n* into the tube, lifts the valve *k*, and fills the space *e f b c*. Thus, by the exit of a portion of the air contained in the bell, the remainder must have become rarified. The piston is now again pushed down into the cylinder. The rarified air in *e f b c* being thereby compressed and consequently condensed, the valve *k* will remain firmly closed, and the air will force open the valve *h*, and makes its exit through the opening in the piston.

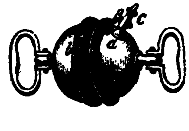
By repeating this operation, the air is continually rarified until its tension no longer suffices to lift the valve *k*; in which case no farther rarification can be produced.

We now proceed to illustrate this remarkable phenomenon.

The bell now no longer contains any air, the tension of which would counteract the pressure of the external atmosphere upon the bell. The latter is, therefore, pressed down with such power upon the plate, that it cannot be removed by the application of considerable force. It is only after admission of air into the bell by means of the cock *l*, that we are once more enabled to remove it with ease.

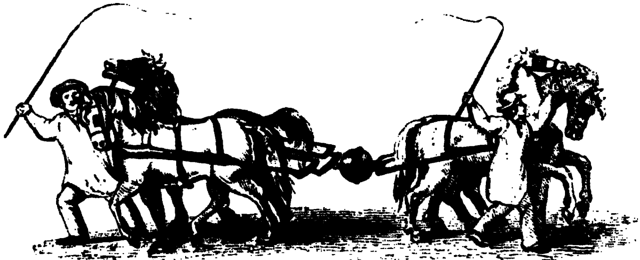
103. Of the many remarkable experiments that may be made by means of the air-pump, we will mention one in particular that has attained historical celebrity.

Otto von Guerike in Magdeburg, the inventor of the air-pump, constructed two hollow hemispheres of copper, the edges of which fitted accurately to each other (fig. 77). The latter were rubbed over with grease, pressed tightly together, and the globe was then exhausted of air, through the cock *c*. The two hemispheres, that fell asunder before exhaustion, were now pressed together by the external air with such force that several horses, attached to the ring of each hemisphere, could not exert sufficient force to separate them.



77.

This beautiful experiment was performed, in the year 1650, to the great astonishment of all beholders, at the Imperial Diet at Ratisbon, in the presence of the Emperor Ferdinand III. and a number of princes and nobles.



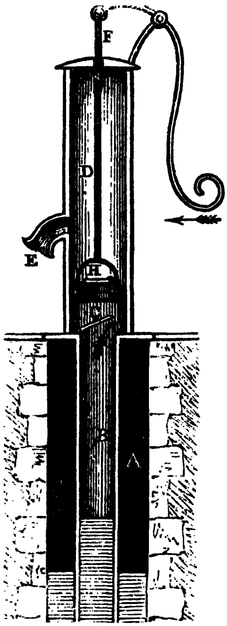
78.

It may be shown, by means of the air-pump, that all bodies fall with equal velocity when in a vacuum, and that animals cannot exist therein; and a number of other phenomena are produced by the aid of this instrument, of which mention can be made only hereafter.

104. Many phenomena, such as respiration and suction, and many important instruments, as the suction-pump and fire-engine, depend upon the pressure of the atmosphere and the production of rarified spaces.

By enlarging the space of the cavity of the chest, by means of particular muscles, the air contained therein is rarified, and a fresh portion enters from the atmosphere; thus *inhalation* is produced. On the contraction of the sides of the chest by the muscles, the air contained in the cavity is compressed and escapes; this is termed *exhalation*.

On immersing one end of a glass tube, the stem of a pipe, or a reed, into water, and applying suction to the other end, the air will become rarified, and the water will be forced upwards by the pressure of the external air.



79.

An arrangement for effecting suction by means of the air-pump, instead of the mouth, is termed a *pump*.

105. The pump consists of a *reservoir* (fig. 79), generally speaking, an underground cistern, into which extends the *suction-pipe* B, which may be closed by the valve C. Above this are situated the *cylinder* D and the *spout* E of the pump. The cylinder contains the *piston-rod* F of the perforated piston, with the *piston-valve* H.

On raising the piston the air in the space beneath is rarified, and causes the valve H to remain closed; while C opens and admits the water from the suction-pipe into the cylinder. On the piston being depressed the valve C is closed; the water that has been raised above it forces open the valve H, and passing thereby through the piston, reaches the upper portion of the cylinder, whence it flows out when it arrives at the spout. The number of strokes to be made with the piston before the water flows out of the spout of the pump depends upon the relative size of the various parts of the instrument.

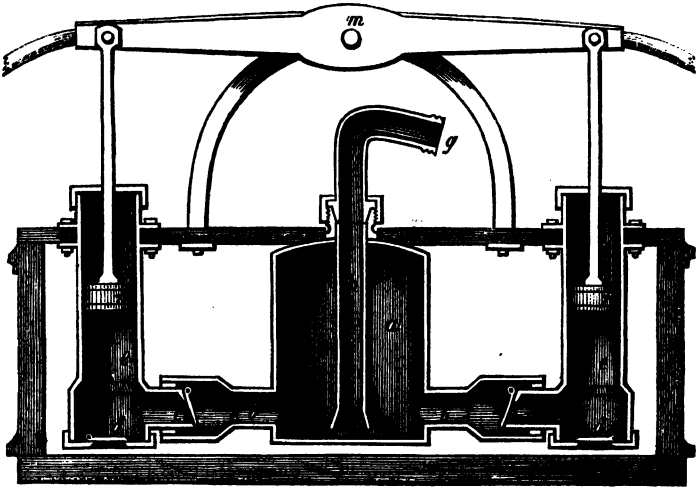
106. Water cannot, however, be raised to any height by means of the suction-pump; because the pressure of the atmosphere is incapable of forcing water higher than about 32 feet. We have ascertained (§ 96) that it is capable of maintaining in equilibrium a column of mercury 30 inches in height; water being thirteen times lighter than mercury, a column of water 13×30 inches in height is required to counterbalance the pressure of the column of mercury, or the pressure of the atmosphere.

The height of the first valve above the surface of the liquid should, therefore, not exceed 30 feet. It is still possible to raise the water in the cylinder, but not to a much greater height, as the operation of pumping becomes too laborious.

If, therefore, water is to be raised from a considerable depth, or to great height, *forcing-pumps* of peculiar construction are substituted for the suction-pump.

107. The action of the *fire-engine* (fig. 80) depends principally on the increased tension of compressed air. The various parts of this machine are situated in a large vessel or cistern, which is kept continually filled with water. In its centre is fixed a strong receiver, *a*, called the *air-chamber*, in which the tube *g* reaches nearly to the bottom. When the engine is about to be used, this tube is first closed at *g*, by means of a cock. Water is now pumped into the air-chamber by means of the two suction-pumps *e e*, and as the air cannot escape from the former, it becomes more and more compressed

therein, as fresh quantities of water are introduced. When the pressure has attained a certain force, the cock at g is opened, and the compressed air at the



80.

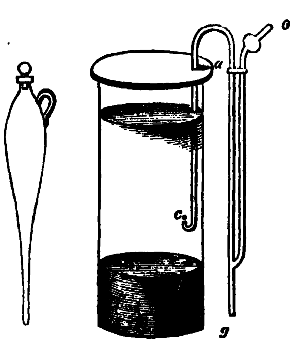
top of the chamber immediately drives out a jet of water with great force through the opening of the pipe. As water is continually pumped into the air-chamber, an uninterrupted jet is thus obtained.

The manner in which the air-chamber acts may be easily shown by half filling a little bottle with water, corking it up, and fitting a small glass tube, or the stem of a pipe, air-tight, into the cork, so as to reach nearly to the bottom of the bottle. On blowing forcibly into the tube with the mouth, the air in the vessel becomes compressed, and as soon as the external pressure at the mouth of the tube is removed, a jet of water will be forced out of the glass. (Fig. 81.)

108. If a tumbler be perfectly filled with water, the surface covered with piece of paper, and the glass then inverted, the water will not flow out, being prevented from so doing by the pressure of the atmosphere against the external surface of the paper. The use of the paper is merely to enable the experimenter to invert the glass, and to prevent any water from running out at the sides, or particles of air from entering in its place. If the lower opening is sufficiently narrow to prevent the efflux of the water, as is the case with the dipping-syphon, the paper is no longer required. The *dipping-syphon* (fig. 82) is a tubular vessel, somewhat contracted above and below, and open at both extremities. If it be immersed in a liquid it will become entirely filled, and, by closing the upper orifice with the thumb, the syphon may be lifted up without any of the fluid contained in it escaping.

81.

A modification of the common syphon, known as Mitscherlich's syphon (fig. 83), consists of a bent tube $g\,c$, whose legs are of unequal length, the shorter one being curved upwards, as shown at c, for the purpose of drawing a liquid from above downwards, and thus removing it with more facility from the precipitate d. If, after the shorter leg is plunged into the solution, the whole tube be filled by closing with the finger the lower aperture g, and sucking out the air at o, the liquid, on removal of the finger, will continue to run out at the end of the longer leg g, and may thus be perfectly separated without disturbing the precipitate. The action of the syphon is readily explained: the column of liquid in the longer leg, and that reaching in the shorter leg from the curve to the surface of the fluid in the vessel, have both a tendency to obey the law of gravity. This tendency, however, is opposed on both sides by atmospheric pressure, acting on the one side at the aperture g, and on the other upon the surface of the liquid in the vessel; thus preventing, in the interior of the tube, the formation of a vacuum which would take place at the curve if the two columns ran down on both sides. By the pressure of the atmosphere acting with equal force, a perfect equilibrium would be established if the columns of water were equally high in both legs; that is, if the opening were at the elevation of the level of the water in the vessel; as soon, however, as g lies deeper than c, the column in the longer leg preponderates, and, in proportion as the liquid escapes, a fresh portion is forced into the tube on the other side by the pressure of the air, so that the liquid continues to flow out at g until the level has fallen to the height of the aperture c.



82. 83.

II. PHENOMENA OF VIBRATION.

109. We are now about to enter upon the consideration of a class of phenomena differing widely from those already examined, both by their impressions upon our senses, and by the manner in which we arrive at a conception of their origin and nature.

However much the most zealous and ingenious philosophers have enriched us with their experiments and the deductions they have arrived at, it still remains a difficult task to form a clear and definite idea of the nature of these phenomena.

110. We have become acquainted with *matter* as something occupying space, obeying the laws of mutual attraction, and under every form possessing weight. It is now necessary to enter upon the consideration of a class of phenomena which are independent of weight.

The term *Ether* has been adopted to express something opposite to matter; something that is not accumulated, like the latter, into bodies in different parts of the universe, but distributed over the whole in a state of infinite subtlety. Ether, therefore, penetrates even matter; and we cannot conceive an idea of a substance without every particle thereof being surrounded by ether. As it

does not occupy space in the same manner as matter, and is not influenced by attraction, it exists equally in the rarified space of the air-pump and in the perfect vacuum of the barometer. It exists in everything, just as though the whole universe had been immersed in ether, and had become completely and eternally penetrated by it.

But how are we to recognise the presence of that in which all the properties by which we distinguish material bodies are absent? Ether also possesses its peculiar properties, by which alone we are enabled to form a conception of it.

Besides being possessed of exceeding *subtlety*, ether is also endowed with the highest *mobility*, and only becomes evident to our senses when in motion. Its slightest vibration distributes itself, therefore, over a great distance, until, as it reaches our senses, it produces sensations which we describe as *heat* and *light*. Other kinds of motion of ether render themselves perceptible to us by the production of phenomena which we comprise under the names of *Electricity* and *Magnetism*.

Scientific men naturally hesitated in adopting a conception of ether; for it is one of the most important principles in science to assume the existence of that only which may be made directly perceptible to the senses. Although this has not been possible as yet with regard to ether, we are enabled to increase our belief in its reality by calling to our aid that which is most similar to it, and which renders its existence more probable.

No man doubts the existence of the *mind* or the *soul*. Though invisible and incomprehensible to us, we are convinced of the presence of the soul by the wonderful and manifold actions of which it is capable on the slightest impulse.

And why should it be a matter of such difficulty to exalt our ideas to the conception of ether as something supermaterial, of exceeding fineness, after having become acquainted with water existing as a solid, a liquid, and a gas? There was a time when the conception of air as a body, presented to the mind a greater difficulty than does now the assumption of the presence of ether in the universe.

Our belief in the existence of ether finds its principal support in the fact that through this assumption we are enabled to form connected and sensible ideas of a variety of phenomena, and, indeed, to predict them, and confirm such by experiment, that we could not otherwise satisfactorily account for in any manner. It should, however, be observed here, that this physical ether must, by no means, be confounded with the fluid known in chemistry by the same name.

Vibrations in General.

111. A peculiar vibratory motion may be imparted to matter as well as to ether. The vibrations of matter produce in us the sensation of *sound*; while those of ether render themselves perceptible as *heat* and *light*.

As the clearest conception can be formed of vibrations by comparing them to the waves produced by throwing a stone into smooth water, the term *undulatory* or *wave motion* has been adopted in general to express the phenomena of vibrations.

A distinction is made between *standing* waves and *moving* or *progressing* waves. The former are produced by taking hold of a stretched cord or string in the centre, drawing it on one side, and then leaving it to itself. Progressing

waves are formed by throwing a stone into water, or giving a blow to a tightly-stretched cord. The difference between these waves depends upon the following principles:—

When the state of rest or *equilibrium* of a stretched cord is disturbed, by imparting to the latter an undulatory motion, every portion of the cord returns for an instant, at each vibration or wave that it describes, to the position of equilibrium; or, in other words, the position of equilibrium is passed. Progressing waves differ particularly from standing waves in the circumstance that, with the former, the various vibrating parts will only pass the position of equilibrium one after the other, while it is simultaneously performed by the vibrating points of a standing wave.

The waves of water are well known to spread themselves in uniformly-increasing circles over the whole surface, so that the most distant portions of the water are gradually set in motion Water-waves consist of alternate elevations and depressions. The whole number of waves, produced by throwing a stone into water, is termed a system of waves.

The meeting of two different systems of waves, produced, for instance, by throwing two stones into the water, is accompanied by very peculiar phenomena. On their coming in contact, the elevations of the one system may meet with those of the other, and the wave depressions of the two systems may likewise come in simultaneous contact with each other, the result being the production of higher elevations and deeper depressions; or an elevation of one system may meet a depression of the other, in which case it is obvious that the two waves will counteract each other, and the undulatory motion will cease. This so-called *interference* of wave-systems produces *points of repose* or *nodes;* several of these, situated side by side, form lines of repose or *nodal lines.*

On progressing waves meeting with a sufficient impediment, their farther progress is not only prevented but they are also thrown back. If, therefore, the waves moving along from one end of a cord meet with others coming in the opposite direction, nodal lines are also easily produced, the cord being divided by them into a number of standing waves.

Undulatory motions are most powerful at the point where they originate, and at the moment when they commence. They become smaller and decrease in power with every succeeding fraction of time, the farther they spread from the point where they originated. Sound, heat, and light, therefore, decrease in strength the farther we are distant from the point of their origin; this decrease of power stands in direct ratio to the squares of the distance.

The waves of a vibrating string proceed only in the direction of its axis. The waves of water spread in circles, which increase in size from the point of origin on the horizontal plane of the surface. But in order to understand the vibrations of air and ether we must avail ourselves of another illustration. The point, for instance, at which a sound commences, we may consider as the centre of an infinite number of strata of air which surround that point in the form of hollow spheres of gradually increasing magnitude. The sound is farther spread, from the inner to the outer, by the progressive vibrations of all these spherical strata of air. These vibrations consist of the alternate approaching and receding of the strata of air, by means of which condensations and rarifactions are produced. By the same laws, heat and light diffuse themselves from the point of origin in *all directions.*

Straight lines which proceed from the centre through the circles of water waves, or through the spherical surfaces of vibrating air, are called *wave-rays*, and hence we speak of ray's of sound, heat, and light.

A *difference* may, however, exist among the vibrations, according to the length or height of the waves, originally set in motion, as also according to their direction and velocity, *i. e.*, the number of vibrations occurring within a certain time. It will be seen that these differences exercise considerable influence over the phenomena resulting from undulatory motion.

We have now endeavoured to arrive at a general conception of the nature of sound, heat, and light; we must not, however, omit to state that the above is not the only view by which these natural phenomena, so remarkable in their appearance and effects, are accounted for.

It is not so much our object in this work to enter into the investigation of theories, or to compare the views of different philosophers, as to arrive at a knowledge of the most important facts which have been gleaned from nature by scientific men. It is our intention to communicate these, making use only of the most popular expressions, even if they should not always agree exactly with the view entered into above. *Muller's undulatory disc* is of great assistance for attaining a proper conception of wave motion.

I. Sound.

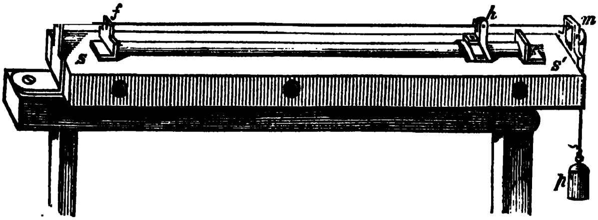
112. Daily experience teaches us that scarcely any motion of surrounding objects can take place without producing an audible sound. We may say with certainty, that every sound is the result of the vibrations of a portion of matter, and the nature of the tone or sound depends only on the manner in which these vibrations arise. Sounds generally reach our ears through the air, as waves of sound. These are produced by the alternate condensation and rarifaction of the air at certain points. With wires, bells, and tuning-forks, it is the bodies themselves that produce the sound which the air only serves to convey. In wind instruments and the human voice, it is the vibrating columns of air that sound.

The following remarks hold good in general with regard to sound: the height or depth of a tone depends on the number of vibrations made by the sounding body in a given time. The smaller the number of vibrations, the deeper is the tone, and *vice versâ*. The length of the different sound-waves stands in the closest relation to the tone produced. The deeper notes are produced by the longer, and the higher ones by the shorter sound-waves.

The deepest tone that can be produced, results from vibrations, of which 14 or 15 are performed in one second. The deepest note that is applied in music, is that obtained by the organ-pipe of 16 feet length, closed at its upper end, which produces sound-waves of 32 feet. On the other hand, there exist high notes, the vibrations of which number 48,000 in a second. The wave-length of the highest musical notes is 18 lines. Higher or lower tones than the above-named can no longer be clearly distinguished by the ear, and are, therefore, not accepted as notes.

113. The phenomena of vibrating strings may be most conveniently examined by means of a string or wire (fig. 84), which may be lengthened or shortened by a moveable bridge, and stretched more or less forcibly by weights attached to one end.

It may be easily proved by means of an arrangement of this description, that the number of vibrations of a string is the *greater*, the *shorter* and the *thinner*



84.

it is, and the *tighter* it is *stretched*, and lastly, the smaller the *density* of it is. Such strings consequently produce the highest tones.

The depth of tone of a string increases, therefore, with its thickness, density, and length, and with the decrease of the tension. The strings of the piano or harp are examples of this. Those strings which are to produce the deepest tones, on the violin and double bass for instance, are covered with metallic wire, whereby their specific gravity is increased. Strings of equal length may possess different tones, according to their comparative thickness, or the unequal force with which they are stretched.

114. If we now notice a tone which has a certain number of vibrations, and call it, for instance *c;* the note that makes just double the number of vibrations in the same space of time, is called the *higher octave*, and the one that only performs half the vibrations, the *lower octave*, of C. Between every note and its octave, there are six other notes, the names and vibrations of which are as follows: —

Key note.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Octave.
c	*d*	*e*	*f*	*g*	*a*	*b*	*c*
1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2

These relations of the numbers of vibration are the same through all octaves and for all notes, by whatever instrument they may be produced. If the deep note C produced by the 16-feet pipe makes 32 single or 16 double vibrations in a second, its octave will make 64, its third 40, its fifth 48, &c.

The ratios between the numbers of each two consecutive notes in this series are not alike. In the following list, the fraction placed by the letter denotes than how much greater the number of vibrations of each following note is, that of the preceding one :—

c		*d*		*e*		*f*		*g*		*a*		*b*		*c*
	$\frac{1}{6}$		$\frac{1}{9}$		$\frac{1}{15}$		$\frac{1}{8}$		$\frac{1}{9}$		$\frac{1}{8}$		$\frac{1}{15}$	

d therefore makes $1\frac{1}{8}$ times as many vibrations as *c* in a given time, *e* $1\frac{1}{9}$ times as many as *d*, *f*, $1\frac{1}{15}$ times as many as *e*, &c.

The intervals from *c* to *d*, from *d* to *e*, from *f* to *g*, from *g* to *a*, and from *a* to *b*, are called *whole tones*, and measure either $\frac{1}{8}$ or $\frac{1}{9}$. On the other hand, the intervals from *e* to *f*, and from *b* to *c*, are called *semi-tones*, as they measure only about one-half of the above spaces, namely, $\frac{1}{15}$. In order,

however, to be able to proceed from any note, with the intervals as they are given above, it becomes necessary first to introduce semitones between *c* and *d*, *f* and *g*, *g* and *b*, giving to them the names *c* sharp, *d* sharp, *f* sharp, *g* sharp, *a* sharp.

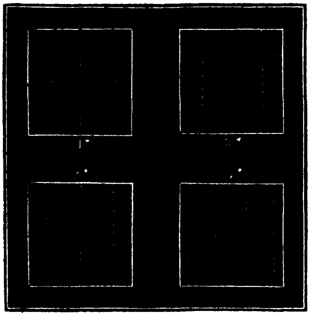
The key-note always forms with its octave, third, or fifth, a *consonance*, with all together a *concord;* and with its second, or seventh, a *discord.*

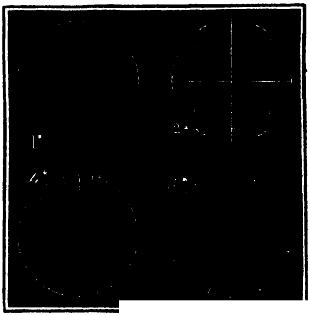
115. If a stretched wire be supported in its centre by the bridge, and the one half stroked with the bow, the other half will also vibrate: this may be proved by placing small paper *riders* on the latter, which will be thrown off by the vibrations.

If the string be supported by the bridge at one-third of its length, and the other two-thirds be covered with paper riders, they will all fall off on the first-third of the string being stroked with the bow, with the exception of those which are situated exactly on the second third of the string. This point consequently does not participate in the vibrations of the string, and is, therefore, termed the *nodal* point. On supporting the string at one-fourth of its length, it is divided into four vibrating parts, with two nodes or points of repose, and so on.

When discs, bells, or plates are sounded, the vibratory motion is likewise not imparted equally to all parts. This, for instance, may be rendered perceptible by strewing a glass plate with fine sand, laying hold of it at one point and stroking its edge with the bow. The vibrating portions of the glass will cast the sand on to those points of repose which will form nodal lines in various mutual directions.

By employing square or round plates of glass, and by altering the point of support, the place where the vibratory motion is imparted, or the force with which it is imparted, a variety of *sound figures* may be produced, such as are shown in figs. 85 and 86.





85.

116. Sound distributes itself in all directions, the vibratory motion being imparted from one particle to those which surround it. This proceeds with great velocity, for it has been observed that sound travels, in the ordinary atmosphere, at a rate of 1,050 feet in a second. Its velocity is, however, far surpassed by that of light, as may be observed when a gun is fired off at a distance. The fire and smoke are first seen, and the report is heard only some time afterwards.

We see the lightning before we hear the thunder that is produced simultaneously, and we judge correctly of the distance of the storm by the interval that elapses between the observation of both.

It is remarkable that sound passes much more rapidly through denser bodies than it does through those which are of less density. It is well known that the roar of cannon, the trampling of horses, &c., may be heard at a much greater distance by holding the ear to the earth, than merely by listening in the open air. Water also conducts sound to a great distance: and fish will hear the sound of a bell or fife summoning them to be fed.

At considerable altitudes, where the air is less dense, the sound of the voice is more feeble, and the report of a musket is not audible at so great a distance.

If, however, the sounding vibrations are imparted to a body in vacuo, they cannot communicate beyond that body, and will, therefore, not be heard. This experiment may be easily made by means of the air-pump. A bell, suspended and struck in a vacuum, will not be audible. As soon, however, as air is admitted into the space, the sound will be distinctly heard.

117. When the sound rays, passing through the air in a straight direction, meet with denser objects, the direction of their course will be more or less altered. They may indeed, if they meet with a solid obstacle, be perfectly repelled or reflected like the water-waves on the sea-shore. The phenomenon of reflected sound is called *echo*. In order to hear an echo of one syllable, the observer must be at least 60 feet from the surface whence the sound is reflected; for an echo of more syllables the distance must be from 116 to 120 feet.

Speaking-tubes are employed for the conveyance of sound, particularly of language. They are tin tubes, about one inch in diameter, and extending from one story or room to another, or from the mast-head to the deck of a vessel. A word spoken into one end of the tube will be distinctly heard at the other end, the sound-waves being prevented from dispersing.

The *speaking-trumpet* is a cone-shaped instrument, likewise serving to retain the sound-waves more together, by which means they may be directed with particular force in one direction. On the other hand, a similar instrument is employed as a *hearing-trumpet*, the wide opening of which collects the waves of sound, and conducts them to the ear.

II. HEAT.

118. The conditions which we term *hot*, *warm*, or *cold*, appear to be the results produced by certain vibrations of matter. These conditions are not really opposed to each other, but may be regarded as different degrees of one general phenomenon which we call *heat*, and which, besides rendering itself sensible to our feelings through the above conditions, always exerts an influence on the expansion of bodies.

On inquiring into the proximate causes of heat, they will be found to be various. Heat renders itself sensible when two bodies are rubbed or knocked together. It is well known that savages obtain fire by the friction of two pieces of wood, and that the smith can make a nail red-hot by the proper management of his hammer. A great quantity of heat is likewise disengaged in the turning or boring of metals. When bodies are reduced to a higher degree of density, a considerable evolution of heat takes place; as for instance, by the rapid and powerful compression of air, and by the slacking of lime.

Various and important phenomena of heat are the results of *chemical* combinations which are unceasingly proceeding in Nature. The best known of these is the process of combustion, which is commonly applied by us to the production of heat for our own purposes. Even the chemical decomposition of food continually proceeding in the human body is an abundant source of heat. Electricity likewise produces considerable heat, as is proved by the effects of lightning.

The earth, moreover, possesses in itself a certain amount of heat, which is but slightly perceptible on its surface, but becomes more sensible to us at some depth, so that we have reason to assume the existence of a considerable degree of heat in the interior of the earth.

Finally, we regard the sun as the principle source of the heat felt on the surface of the earth, as rays of heat, besides those of light, are daily imparted by it. If the earth were not under the influence of solar heat it would differ widely in its nature from its present state.

Whatever may be the source whence heat is derived, it always exhibits the same phenomena in its relation to other objects.

Expansion by Heat.

119. One of the most common phenomena produced by heat, which is sensible to the eye, is the expansion of bodies. It has already been shown (§ 17) that the solid, fluid, or gaseous state of matter is entirely dependent on the influence exercised thereon by heat.

Examples of this expansion may be easily found. A metallic ball, which is a little too large to pass through a ring of metal, will, on the latter being heated, fall through it with ease, the ring being expanded by the heat.

If a vessel be filled completely with a liquid, and the latter heated gradually, it will soon flow over the edge of the vessel, in consequence of its expansion.

A bladder, pressed together, with the opening firmly tied up, but containing still a little air, will, on being warmed, assume the same form as if it were inflated with the mouth, in consequence of the expansion of the enclosed air.

87.

120. The expansion of bodies furnishes a very valuable means of comparing the effects of heat, and likewise of measuring its increase. Heat, as far as it exerts its influence on the comparative expansion of bodies, is termed *temperature*, and the instrument employed for measuring the latter is called a *thermometer* (fig. 87).

The thermometer, like other important philosophical instruments, as the pendulum and barometer, possesses the advantage of great simplicity.

A glass tube is chosen for the construction of the thermometer, the bore of which is perfectly uniform throughout, having about the width of a moderate-sized needle. A small bulb is blown at one end, and then filled with pure mercury. The mercury is now heated, upon which it expands, and fills the whole tube, which is from 6 to 10 inches in length. As soon as the mercury is at the point of protruding from the tube, the latter is sealed, so that it now contains no air whatever, but only the mercury, which on cooling again contracts, so as to stand to about one-third or one-fourth of the height of the tube.

When a tube thus prepared is immersed in melting ice, the column of mercury will stand at a certain height, which is accurately noted by a mark made on the glass tube. The thermometer is then placed for some time in boiling water, and the height to which the mercury rises likewise marked.

Whenever the thermometer is introduced into melting ice or boiling water, the mercury will stand at exactly the heights already noted, which shows that a body always occupies the same space at an equal temperature, and that this space decreases proportionately as the body becomes colder.

The point to which the mercury sinks, when the thermometer is immersed in melting ice, is indicated by a *nought*, and is called the *freezing-point*. That point to which the mercury rises, when the thermometer is plunged into boiling water, is called the *boiling-point*.

When, therefore, the thermometer is placed in any other position, we can judge of the surrounding temperature from the point at which the mercury stands in the tube. We called the temperature *high* if the mercury is near to the boiling-point, and *low* if it approaches the freezing-point.

In order to give greater accuracy to such determinations of temperature, the space between the two points above mentioned is divided into a number of equal parts, which are called *degrees*. This division of the tube is also extended beyond the freezing- and boiling-points; those degrees that are situated above the former are termed *heat-degrees*, and are denoted by the sign +, while those below the freezing-point are called *degrees of cold*, and are indicated by the mark −.

121. In some thermometers the distance between the freezing- and boiling-points is divided into 80 equal parts. This scale of divisions was first made by Reaumur, after whom it has been named: this kind of thermometer is most frequently employed in Germany. In France and in scientific works a thermometer, with a scale of 100 divisions, or the *Centigrade* thermometer, is adopted, in which the boiling-point stands at 100°. But in this country a thermometer, with a perfectly different scale, constructed by *Fahrenheit*, is most generally employed. The following comparative table will most clearly show the relation existing between the different scales:—

Fahrenheit Scale.	Centigrade.	Reaumur.	——
− 4°	− 20°	− 16°	
+ 14	− 10	− 8	
32	0	0	Every 5 degrees on the Centigrade scale are here seen to be equal to 4 degrees on the Reaumur scale. In order to prevent mistakes in the statement of temperatures, it is customary to describe particularly the scale employed. Thus, for instance, + 15° F. signifies 15 heat degrees on the Fahrenheit scale; or − 16° C. is equal to 16 degrees of cold on the Centigrade scale.
50	+ 10	+ 8	
68	20	16	
86	30	24	
104	40	32	
122	50	40	
140	60	48	
158	70	56	
176	80	64	
194	90	72	
212	100	80	

122. The following is a Table of a number of Temperatures worthy of notice:—

—	Fahrenheit.	Centigrade.	Reaumur.
Freezing-point of spirit of wine - - -	−68°	−90°	−72°
Freezing-point of mercury - - - - -	−40	−40	−32
Temperature at the Polar regions - -	−32·8 to −40	−36 to −40	−28 to −32
Lowest winter temperature - - - - -	10·4 to − 4	−12 to −20	−10 to −16
Freezing-point of water - - - -	32	0	0
Greatest density of water - - - - -	39·2	+ 4	+ 3·1
Temperature of the bodies of fishes - - - - - (Dependent on the surrounding medium.)	59 to 77	15 to 25	12 to 20
Temperature of the bodies of many amphibious animals (Dependent on the surrounding medium.)	59 to 86	15 to 30	12 to 24
Mean temperature of Frankfort-on-the-Maine	48·2	9	7
Mean temperature of a room - - -	68	20	16
General summer heat - - - - - -	68 to 77	20 to 25	15 to 20
Higher summer heat - - - - -	75·2 to 96·8	24 to 36	19 to 28
Mean temperature of the Equator - -	84·2	29	23
Temperature of the human body, or blood heat	98·6	37	29
Boiling-point of ether - - - - - -	95	35	28
Temperature of the bodies of birds - -	107·[illegible]	42	34
Melting-point of wax - - - - - -	154·4	68	54
Temperature at which phosphorus ignites -	167	75	60
Boiling-point of alcohol - - - - -	172·4	78	62
Boiling-point of water - - - - - -	212	100	80
Melting-point of sulphur - - - - -	226·4	108	86
Melting-point of lead - - - - - -	611·6	322	257
Boiling-point of sulphuric acid - - -	618·8	326	260
Boiling-point of mercury - - - -	680	360	288
Melting-point of silver - - - - - -	1832	1000	800
Melting-point of cast-iron - - - - -	2192	1200	980
Melting-point of gold - - - - - -	2282	1250	1000
Melting-point of bar-iron - - - - -	2912	1600	1280

It is very remarkable, in the preceding series of temperatures, that water at + 4° C. (39° F.) is denser than ice. It is, however, owing to this exception that in winter the waters of our rivers are not frozen to the ground.

123. As mercury freezes at − 40° C. (− 40° F.), we employ, for the determination of very low temperatures, thermometers filled with alcohol, coloured red. Degrees of heat, situated near or above the boiling-point of mercury, can likewise be no longer determined by a mercury thermometer. The various methods employed for the determination of such high temperatures are all attended with difficulties; the expansion of air presents the means upon which most reliance can be placed.

The expansion of solid bodies, particularly of steel, is applied to the construction of other kinds of thermometers, which find, however, but little application.

124. The force with which bodies are expanded by heat is exceedingly great. The strongest vessels, when filled with water or air, tightly closed and heated, are often incapable of withstanding the force of expansion. It is of

great importance in many respects, particularly in the construction of machinery, to know the extent to which solid bodies expand at certain differences of temperature: determinations of this description have been made with the greatest accuracy.

The fracture of solid bodies in consequence of unequal expansion, such as the cracking of a tumbler when placed on a stove, is of very frequent occurrence, and admits of a simple explanation. The lower particles of the glass become heated and expanded sooner than the upper ones, which still remain in their original state. Hence a tension or pressure is produced in the glass, frequently causing it to crack. The thinner the glass, or the more gradually it is heated, for instance by placing paper under it, the less likely will there be an unequal expansion, and, consequently, danger of fracture.

125. A second result of the expansion of bodies by heat is the decrease of their density. This is particularly perceptible with fluid and gaseous bodies. If water is heated in a vessel, the lower strata, which become heated first and are thereby rendered less dense, rise to the surface, while the colder portions sink to the bottom of the vessel. A motion is thus produced in the water which is perceptible on the introduction of a fine powder into it. This motion continues until the whole mass of water has attained an equal temperature, and, therefore, uniform density.

A still more rapid motion is imparted to the air by heat. In warmed rooms, the lower stratum of air is frequently quite cold, while the upper portion is already thoroughly warmed. The so-called draughts in stoves are caused only by the ascent of the air heated by the fire. The ascending of warm air may be rendered visible by a very pretty little contrivance. A piece of card-board is cut into a spiral form, and one end is fixed on the point of a knitting-needle, the other end of which is stuck into a piece of soft wood. On standing this upon the top of a stove, the heated air as it ascends will make the card-strip revolve round the needle, thus giving it the appearance of a snake. If a good-sized globe of thin paper be inflated with air, which is rapidly heated, the globe will ascend to a considerable height, and may even be made to remain a long time in the atmosphere, by suspending to its opening, at the bottom, a vessel containing burning spirit.

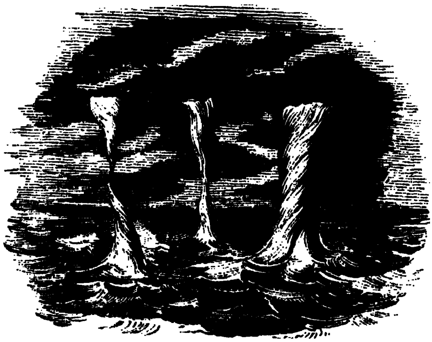
126. *Winds* are, generally speaking, nothing more than currents of air, produced in consequence of the unequal temperature of different parts of the atmosphere. This is most regularly shown by the *trade winds*, which are produced by the ascent of heated air from the equator, and its replacement by dense cold currents of air from the poles. The revolution of the earth, however, tends to give them a direction parallel with the equator, so that, in the northern hemisphere the trade winds follow the mean of the two directions, namely, north-east.

The prevailing land and sea breezes on the coasts are also very regular. After sunrise, a wind sets in from the sea to the land, the latter becoming much more rapidly heated by the sun than the water, so that the warm air ascending from the land is replaced by currents of air coming from the water. After sunset the reverse is the case. The land cools down more rapidly; in consequence of which, currents of air pass from it to the sea. A similar phenomenon is often observed at the entrance of valleys.

Storms are winds of tremendous velocity, travelling at the rate of 120 feet

in a second. They are the results of the sudden condensation of aqueous vapour contained in the atmosphere. The air rushes with great force from all sides into the rarified space thus produced. The circumstance, that the appearance of storms is always accompanied by a fall of the barometer, has led to the above explanation of these phenomena.

If violent winds or storms meet from opposite directions, they produce *whirlwinds*, which often tear away with them all moveable objects to which they impart a circular motion. On land they give rise to columns of sand, and at sea they produce *water-spouts* (fig. 87).



87.

127. In speaking of the density of a body, it is always understood to bear reference to a certain temperature, at which the density was determined. The densities of solid and liquid bodies vary, however, only slightly with small differences of temperature. The determinations of density are generally made at a temperature of 12° to 15° C. (53° to 59° F.).

Slight differences of temperature, however, greatly affect the density of gaseous bodies. According to the most accurate observations, all gases expand to $\frac{1}{273}$ of their volume for every degree on the Centigrade scale, corresponding to an expansion of $\frac{1}{492}$ of their volume for each Fahrenheit degree; 273 cubic inches of air at 15° C. (59° F.) occupy therefore a space of 274 cubic inches if their temperature is increased to 16° C. (60·8° F.), whereas at 14° C. (57·2° F.), they will only occupy a space of 272 cubic inches.

Besides the thermometer, the barometer also shows us that the density of the air is not always the same. For when the barometer stands high, the density of the air is not the same as when its position is low, as air, when charged with aqueous vapour, has naturally a different density to dry air.

These circumstances have, however, been carefully regarded and allowed for, in the determination of the density of gases; when it is, therefore, said (§ 93) that 770 cubic inches of atmospheric air weigh $\frac{1}{4}$ oz., or, what is the same, that air is 770 times lighter than water, it is understood that the density determination was made with dry air at a barometric height of 30 inches, and at the temperature of 0° C. (32° F.). The same conditions hold good for the statements regarding the density of all the other gases.

As we know, however, from § 91, that the spaces occupied by gases bear an inverse ratio to the pressure exerted upon them, and as we are acquainted with the extent to which gases expand for every degree of the thermometer, we may easily find by calculation the density of a gas for any pressure and temperature.

It is now perfectly intelligible why a balloon, filled with warm, and therefore lighter, air, ascends in the atmosphere. We are as little surprised at this as at the rising of a cork to the surface of water.

The circumstance that vines and other plants occasionally are not frozen on

high hills, while they perish in valleys, is likewise accounted for by the ascent of the warm air.

EBULLITION—EVAPORATION.

128. If various bodies are exposed to a high temperature they are either destroyed, as is the case with vegetable and animal productions, or they suffer merely a change of condition.

Solid bodies become fluid at a certain temperature. At § 122 the fusing- or melting-points of various bodies have been enumerated; we have only to add that the same body always melts at a certain temperature; lead, for instance, at 322° C. (611° F.).

If a fused body be continuously heated, a certain point will at last be attained, when its particles will, by the influence of heat, assume the properties of gases. Solid and fluid bodies, when in this state, are called *vapours.* Most bodies may be converted into vapour, although many require a very high temperature to attain that state; but, under these conditions, even such metals as iron, copper, or platinum may be vaporized.

Such bodies as may be converted into vapour at a comparatively low temperature are called *volatile* bodies.

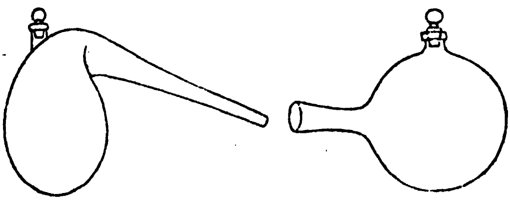
All vapours remain in that state as long as the temperature by which they were formed continues. As soon, however, as it decreases, the body condenses to a liquid, which may afterwards solidify.

129. Two important technical and chemical operations, namely, *sublimation* and *distillation*, are based upon the property which bodies possess of assuming, under the influence of heat, the form of vapour.

The first of these consists in the conversion of *solid* bodies into vapour, and the condensation of the latter in appropriate vessels. The condensed substance is generally deposited as a fine pulverulent body, which is called a *sublimate.* The most simple way of effecting sublimation is by placing a substance, such as camphor, at the sealed end of a glass tube, and applying heat. The camphor will soon be converted into white vapours, which will condense as a fine powder at the upper, cool portion of the tube.

Distillation has found far more frequent application than sublimation. It is employed for the separation of a volatile body from other substances that are not volatile, or only very slightly so. Thus, for instance, at brandy distilleries the volatile spirit in the fermented wash is separated from the remainder by distillation.

A distilling apparatus generally consists of three parts; the still or retort in which the liquid is heated, the condenser in which the vapours are condensed, and the receiver in which the distillate is collected.

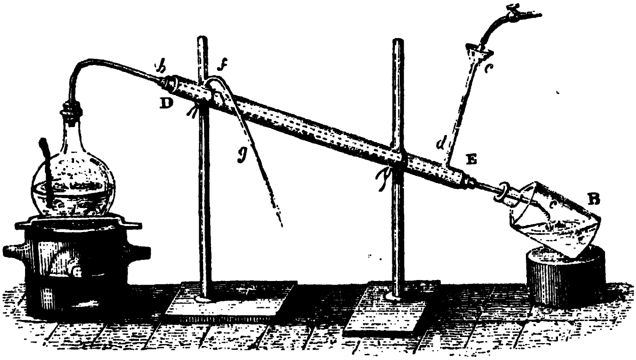


88.

For chemical operations the distilling apparatus usually consists of a glass retort and receiver, (fig. 88); but if the vapours are very volatile other means are required to cool

and condense them perfectly, otherwise a considerable portion would escape into the air and thus be lost.

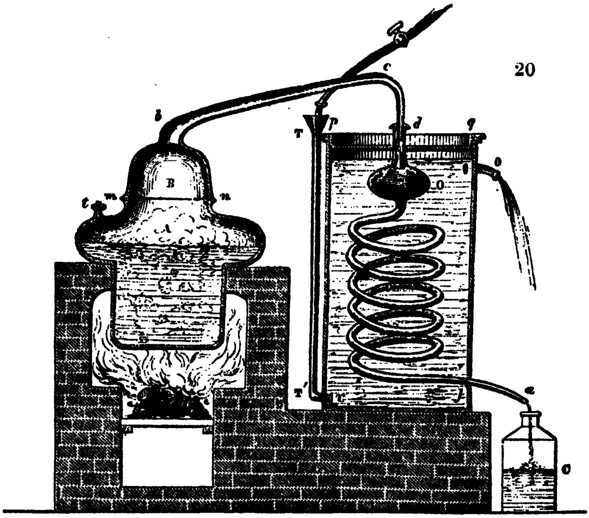
In such cases the arrangements shown in fig. 89 answer exceedingly well for small operations. The vapours generated in the distilling flask pass into



89.

the long glass-tube *b c*, which is encased in a wider one of tin-plate or zinc D E. The space between the two tubes is filled with cold water, which is introduced by the funnel-tube *c d*, whilst the warm water flows out from the tube *f g*. By this arrangement the vapours are perfectly condensed, and may be collected in the receiver B.

An apparatus similar to that shown in fig. 90 is employed for distilling brandy and spirits of wine. It consists of a copper still A mounted in a brick



90.

furnace, and to which is adapted a dome-shaped head B. The head of the

still, terminating in the bent tube *b c d*, communicates with the worm O, which is enclosed in a large cylinder of metal *p q r j*, kept continually filled with water. The fermented liquid is introduced at the tubulure *t*. As the water in the cylinder becomes heated by the condensation of the vapours in the worm, it is necessary from time to time to renew it. This is most conveniently effected by allowing a stream, from a reservoir of cold water, to run slowly through the funnel-tube T T′, which communicates with the bottom of the cylinder. The heated water rises to the surface, and escapes by the tube *o*, whilst the condensed spirit passes out at the inferior extremity of the worm *a*, and is collected in the receiver at C.

It must, however, be remarked that there exists an innumerable variety of arrangements for distilling, which all correspond in the most important points with the apparatus just described, whatever may be their form.

130. When water is heated in an open vessel, its conversion into vapour is opposed by two forces, viz., the cohesion of its own particles and the pressure of the atmosphere, by which they are compressed together. These impediments must, therefore, both be overcome in the formation of vapour.

By the continued heating of water, till it attains the temperature of 100° C. (212° F.), its particles at last acquire a tendency to separate, which is greater than the counteracting forces. From the moment that temperature is attained, bubbles of vapour will be seen to form at the lowest portion of the vessel, to rise to the surface of the water, imparting to it an undulatory motion, and finally to escape into the air. This phenomenon is termed *ebullition* or *boiling*; the tension of the vapour forming the bubbles is equal to the pressure of the atmosphere, otherwise, of course, they could not be formed. In this manner any quantity of water may be perfectly converted into vapour, and it will be observed that, during the entire period that ebullition continues, the thermometer will not rise above 100° C. (212° F.), however large may be the fire applied to the bottom of the vessel. All the heat in this case goes over to the vapours produced, as will be presently shown.

If water be heated to ebullition on the top of a high mountain, and a thermometer introduced, it will be found that the latter will not rise to 100° C. (212° F.). The reason of this may be easily explained. The pressure of the air upon the water is less at this height, consequently the latter must boil at a lower temperature than it would at the common level. On the high plane of Quito, which lies 8,724 feet above the level of the sea, water boils at 90° C. (194° F.). An egg, cannot, therefore, be boiled hard there in an open vessel. If the air in a vessel, containing a little water, be highly rarified or almost entirely removed by the air-pump or other means, the water may be made to boil even by the heat of the hand.

131. When water is exposed in the open air it vaporizes even without the application of heat. This spontaneous evaporation proceeds but slowly, and is called *vaporization*. The rapidity with which a certain amount of water evaporates is proportionate to the extent of its surface in contact with the air, to the dryness and warmth of the latter, and to the rapidity with which fresh layers of air are allowed to pass over its surface.

132. The *amount of moisture* contained in the air is regulated by atmospheric temperature, and by the quantity of available water. A certain amount of air contains more water, if taken from over the surface of the sea in hot

climates, than if obtained from the cold steppes of Northern Asia, or the hot and dry sandy deserts of Africa. The air is *saturated* with moisture, when it contains quite as much water as corresponds to the temperature. When the air approaches to this state it is called *damp*, and when it contains much less water than corresponds to its temperature it is termed *dry* air. This explains why air which is called dry, for instance, in Italy, may, notwithstanding, contain more water than what is termed damp air in colder countries.

When the air is saturated with moisture it can no longer take up fresh quantities, hence water when brought in contact with it will not evaporate or decrease in quantity. As soon, however, as its temperature is increased, it is capable of taking up more moisture. Various means are employed to ascertain the amount of aqueous vapour contained in air. Thus there are many solid substances, as chloride of sodium or common salt, that attract the water from damp air, and become moist or even assume the liquid form, as is the case with potassa.

Other substances only change their form in attracting water. To these belong the porous bodies, particularly those consisting of capillary tubes, as hairs, portions of plants, wool, or strings. Ladies' hair, for example, that curls so beautifully in dry weather, will become perfectly straight in damp atmospheres. Wood swells, musical instruments are put out of tune, and many other phenomena are due to the same cause. An apparatus has been constructed in which a human hair, as it stretches or shrinks, sets an index in motion, whereby a very accurate idea may be formed of the amount of moisture in the air. Numerous other *hygrometers* or *psychrometers* have been constructed, which we shall, however, refrain from describing.

133. If air, saturated with aqueous vapour, be cooled down, for instance by winds, it will of course no longer retain the same amount of water. A portion of the latter is, therefore, condensed, and, if the condensation takes place close to the surface of the earth, becomes visible to the eye as *fog*, or as *clouds* if the vapours separate at a greater height. The formation of fog may be observed on a small scale at every breath we take, when the warm air, saturated with aqueous vapour as it proceeds from our lungs, is exhaled into a colder medium.

Fogs and clouds consist of an immense number of exceedingly small *hollow* globules of water. Although heavier than the air they do not fall to the earth immediately upon their formation, but, like soap-bubbles, are retained, often for a considerable length of time, in suspension by the action of currents of air, and are driven from one place to another.

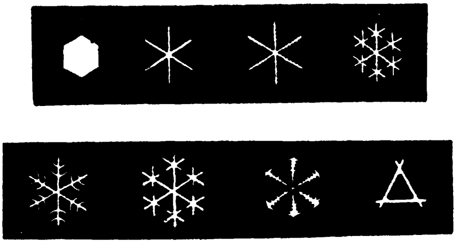
Various names have been given to the clouds, according to their form and mass: thus there are the *feathery cloud* or *cirrus*, the *dense cloud* or *cumulus*, and *stratified clouds* or *stratus*, which again merge into a variety of others, such as the *cirro-cumulus*, *cumulo-stratus*, &c.

134. *Rain* is produced when the clouds, unimpeded by winds, sink down to the lower strata of air, which are saturated with moisture, so that the globules of water increase in size, by the condensation of fresh particles, until they at last form drops of rain, which rapidly increase as they descend to the earth.

The formation of snow is not so easily explained. If we assume damp currents of air to come from warmer regions to much colder ones, the aqueous

vapour they contain may form itself into very minute particles of ice, instead of into globules of water, thus producing snow-clouds, from which these particles of ice descend in flakes of various sizes and forms. By the aid of the microscope the flakes of snow are observed to consist of a large number of regular six-sided prisms, elongated, and grouped around a centre, in such a manner as to form always angles of 60° or 120°. Nos. 2, 3, 4, 5, 6, 7, and 8 (fig. 91) represent some of the most simple groups. But frequently it presents itself in less complicated forms, and sometimes we recognise perfectly regular six-sided plates, as shown in No. 1.

The formation of *hail* is one of those natural phenomena, of which we are as yet unable to furnish a sufficiently satisfactory explanation. It is more particularly difficult to conceive how these pieces of ice are produced, in the height of summer, at no very great altitudes. They are frequently met with of considerable size, weighing upwards of an ounce, and some even from a quarter to half a pound. The destruction effected by hail renders it one of the most fearful scourges to agriculturists. Thus, in the year 1788, a hailstorm passed over the whole of France from the Pyrenees to Holland, destroying in about six hours the crops of 1,039 communities: the loss sustained amounted to upwards of a million pounds.



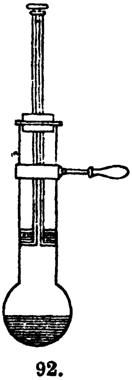
91.

Dew and *Hoar-frost*.—After sunset the surface of the earth radiates towards the sky the heat which is absorbed during the day. It is often cooled down thereby to such an extent that the vapours contained in the lower strata of air are condensed into water, which is deposited as dew upon all the objects on the surface of the earth. As plants, and particularly grasses, possess a stronger radiating power than earth and stones, they are first covered with dew. When the sky is clouded, the nocturnal radiation is impeded by the clouds, and in that case no dew is formed. Thus, dew is likewise not deposited under tents, tables, or other coverings, placed in the open air.

If those bodies on which the dew is deposited, have cooled down to below the freezing point, it is converted into ice, and is then called *hoar-frost*.

135. If common salt, sugar, or other substances are dissolved in water, their solutions must be heated above 100° C. (212° F.) before they will enter into ebullition. Most kinds of food, as they are boiled, possess a higher temperature, and, therefore, such liquids will produce more serious scalds than boiling water alone.

136. If water be heated in a close vessel, so that the steam as it is formed cannot escape, the temperature of the water increases continually, and the vapours acquire a greater tension, the force of which becomes at last tremendous. Strong iron vessels are therefore generally taken for such experiments.



92.

On heating some water in a Wollaston's bulb (fig. 92), the opening of which is hermetically closed by the piston, the tension of the aqueous vapour will soon raise the piston in the tube. If the vessel be now immersed in cold water, by which the steam is suddenly condensed, a rarified space will of course be produced below the piston, into which the latter will again be forced by the outer pressure of the air.

This simple experiment, by forcing up and down the piston, illustrates the principle of the *steam-engine.*

THE STEAM-ENGINE.

137. In the introduction to this work, the invention of the art of printing was spoken of as an event which had secured to science an eternal duration, and furnished it with auxiliary means, without which it would never have attained its present exalted position.

The invention of the steam-engine is of similar importance to the arts. It furnishes man with power equal to hundreds of thousands of hands and numberless horses and beasts of burden. It renders the mariner independent of wind and tide, and sets our mills in motion, whether the streams be dried up or frozen by the winter cold—it overcomes with ease the heaviest weights, and accomplishes the greatest distances with the velocity of the wind.

And as every important alteration in the external conditions of man has an influence on his inward state, so the power of steam has also had important influence over the condition of his mind.

If it is the office of the printing-press to establish and extend ideas and thoughts, it is also an important function of the steam-engine to work out ideas and establish facts; if by the former, centuries are brought into connexion, the latter serves to connect and link together men of the present age.

A space should, therefore, be more particularly set aside in this work for the contemplation of the steam-engine, in order that its power may not appear to us as something supernaturally wonderful, but that it may serve us as a wonderful example of the forces of Nature being made subservient to the mind of man.

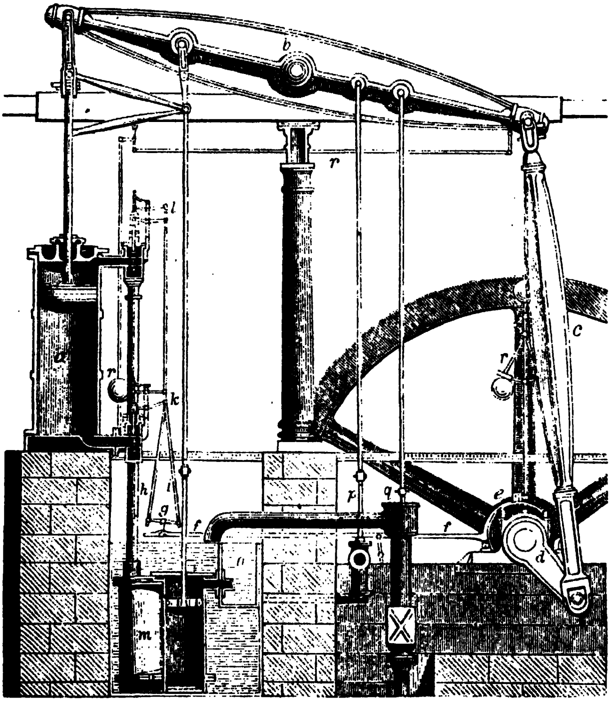
138. The steam-engine derives its power from the tension of confined aqueous vapour heated above the temperature of boiling water. Steam is applied either to *stationary* engines, for steam-mills or steam-vessels, or to *moveable* engines, or *locomotives*, which are used on railways. The construction of these two kinds of engines differs in many respects.

In examining the stationary engine we have first to consider the generation of the steam, and afterwards its application as a motive power.

The steam is generated in an iron *steam-boiler*. There are various forms of boilers, but the main point in their construction is always the exposure of the greatest possible surface to the action of the fire. The general form of the boiler is that of a tube closed at both ends, and perfectly surrounded by the fire. By this means a great quantity of water may be rapidly converted into steam. The latter is conducted by means of a pipe from the boiler into the engine, which we shall now proceed to describe.

Fig. 93 represents a modern double-acting low-pressure engine, which is particularly adapted for impelling machinery. The piston, being acted on by the steam within the cylinder *a*, communicates its required motion to *b* through

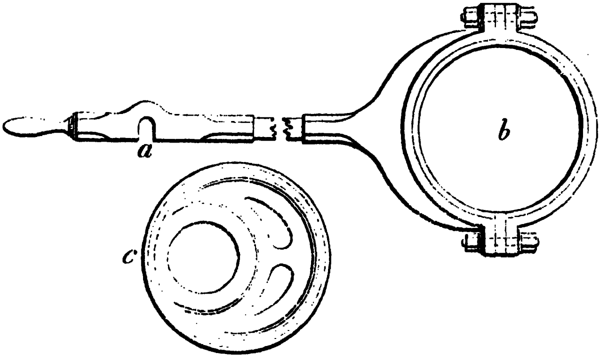
the medium of the piston-rod and the parallel motion which connects it to the beam. To the opposite end of the beam is attached the connecting rod *c*, the



93.

lower end of which being jointed to the crank *d*, a rotatory motion is thus imparted to the wheel; the crank being properly supported on plummer blocks. Affixed to the crank-shaft and behind the crank is what is termed an excentric wheel *e*; so styled from the circumstance of the wheel not being concentric with the shaft upon which it is fixed. The excentric wheel, which it will be seen is merely a convenient substitute for a short crank, has a groove or depression turned round its edge into which a corresponding metal hoop or strap, joined together in two halves, is fitted so as to allow the wheel to revolve easily within it. Fastened to one side of the hoop, and projecting from it horizontally, is the excentric rod, as it is termed, *f f*, which embraces a pin on the end of a lever at *g*. In fig. 94, *a b* represent the excentric rod, and *c* the excentric wheel, each enlarged and detached from each other. It will be observed that the part of the rod, where it embraces the pin of the lever is indented below into a circular hollow, so that it may be disengaged from the lever by being simply raised. Whilst the engine is in action, the excentric wheel, as it revolves, imparts a reciprocating movement, by means of the excentric rod, to the lever at *g*, the axis of which, termed the rocking or wiper shaft, has on opposite sides of it two other levers; these operate on the valves through the medium of the rods *h* and *i* as well as the levers at *k* and *l*.

The spindles of the steam-valves are hollow, and have stuffing-boxes at their upper ends; whilst the spindles of the eduction-valves being longer, are made



94.

to work through the steam-valves, and through the stuffing-boxes so as to be steam-tight. The valves are opened by the action of the excentric wheel, and are closed by weights, which have been omitted, to render what is shown more intelligible.

The condenser *m* is kept exhausted by the air-pump *n*; the water delivered by the latter into the hot well *o* being conveyed to the boiler by the hot-water pump *p*. The cold water necessary to maintain the vacuum within the condenser is supplied by the cold-water pump *q*. The governor *r* is set in motion by bevelled wheels, driven by the engine, and it is supported in an upright position by a frame or bracket. Instead of a sliding collar there is a perforated ball at the top of the governor, and which rises or falls according as the balls of the governor diverge or collapse. A vertical rod extends from the top of the said ball, and it communicates with the throttle-valve by means of a horizontal rod *r*, situated above, as well as by another upright rod, also marked *r*, depending from the latter. At the two points where the various rods join, there is a bell-crank lever that serves to connect them; and it will be observed, a ball is attached near the lower end of the rod next the throttle-valve: the use of this ball, as likewise of the other one immediately above the governor, is to keep the several rods between them stretched, as otherwise each rod would require to be so strong as not to yield by bending. The balls are made to balance each other; and, therefore, according as either is elevated or depressed, the other ball becomes at the same time influenced in the opposite direction.

139. The power of a steam-engine is dependent on the tension or pressure of the steam employed, and on the surface of the piston.

Assuming the steam to have a tension equal to the pressure of the atmosphere, and the surface of the piston to be 1,378 square inches, the latter will, according to § 77, be pressed downwards with as much force as if it were loaded with 20,000 pounds. Supposing, however, the pressure of the steam

to be trebled or quadrupled, the power of the engine will likewise increase in the same degree.

Engines in which steam of low pressure is employed are called *low-pressure* engines, while those that are worked with steam of great pressure are termed *high-pressure* engines.

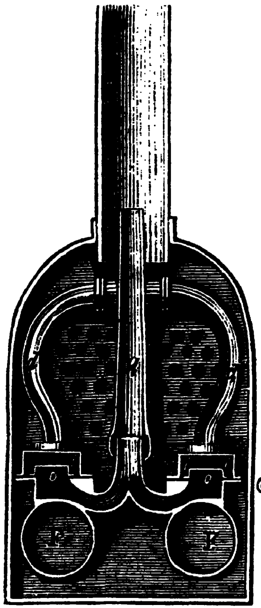
It must not, however, be imagined that low-pressure engines are less powerful than those of high-pressure. The cylinders in the latter are smaller, by which the difference in pressure is compensated for; the force exerted by the pressure of *one* atmosphere on a piston, the surface of which measures *four* square feet, being evidently equal to that of *four* atmospheres on a piston measuring *one* square foot.

The high-pressure engine *consequently* occupies the smaller space, particularly if the steam on the one side of the piston is not removed by condensation, but allowed to escape into the atmosphere. The condenser and the various pumps are not required in that case, and the whole engine becomes much more simple in consequence. This kind of engine is employed for *locomotives*, on account of the small space it occupies.

140. An engine, working at high pressure, requires, in an equal space of time, about the same amount of steam as a low-pressure engine of equal power. The former must, however, be so arranged as to be capable of converting a large amount of water into steam, in a very confined space, and in a short time. This is accomplished by allowing the air, heated in the furnace, to pass through a series of iron tubes which are surrounded by water, as shown in figs. 95 and 96, which represent a longitudinal and a transverse section of a locomotive.

In fig. 95, A A represents the fire-place, which is closed by the door in front. From the fire the heated air has no other channel of escape, than through the series of horizontal tubes which extend from A to D; from D the heated air, together with the smoke, passes through the funnel into the atmosphere. Fig. 96 shows the relative position of these tubes passing through the boiler filled with water, which, moreover, surrounds on all sides the fire-place itself. The water is thus exposed to an extremely large heated surface, which causes at every moment the generation of a great quantity of steam. The steam collects in the space B C above the surface of the water; and from the chamber C passes by the tube *c* into the cylinder. If the position of the mouth of the tube be too low, the rapid ebullition carries a considerable quantity of water mechanically into the tube; but in order to obviate this inconvenience, the chamber is elevated as shown at C. The tube *c* divides into two branches, *d d*, fig. 96, one of which is only seen in fig. 95. Each of these tubes communicates with a chamber from which the steam passes into the cylinder F. On each side of the carriage there is one horizontal cylinder, in which the piston moves in the same direction.

From the chamber *i*, into which the steam is passed by the tubes *c d*, lead two canals communicating with the opposite ends of the cylinder. Upon the bottom surface of the chamber *i* is a sliding valve, which moves backwards and forwards, and whose central part forms a kind of chest *o*, which is open at the bottom. In the position shown at fig. 95, the two canals are closed by this valve. Let us imagine the slide to be pushed so far towards the left hand, that the left canal is no longer closed, but in communication with the cavity *o*, the right hand canal will then be in connexion with the steam chamber *i*; while



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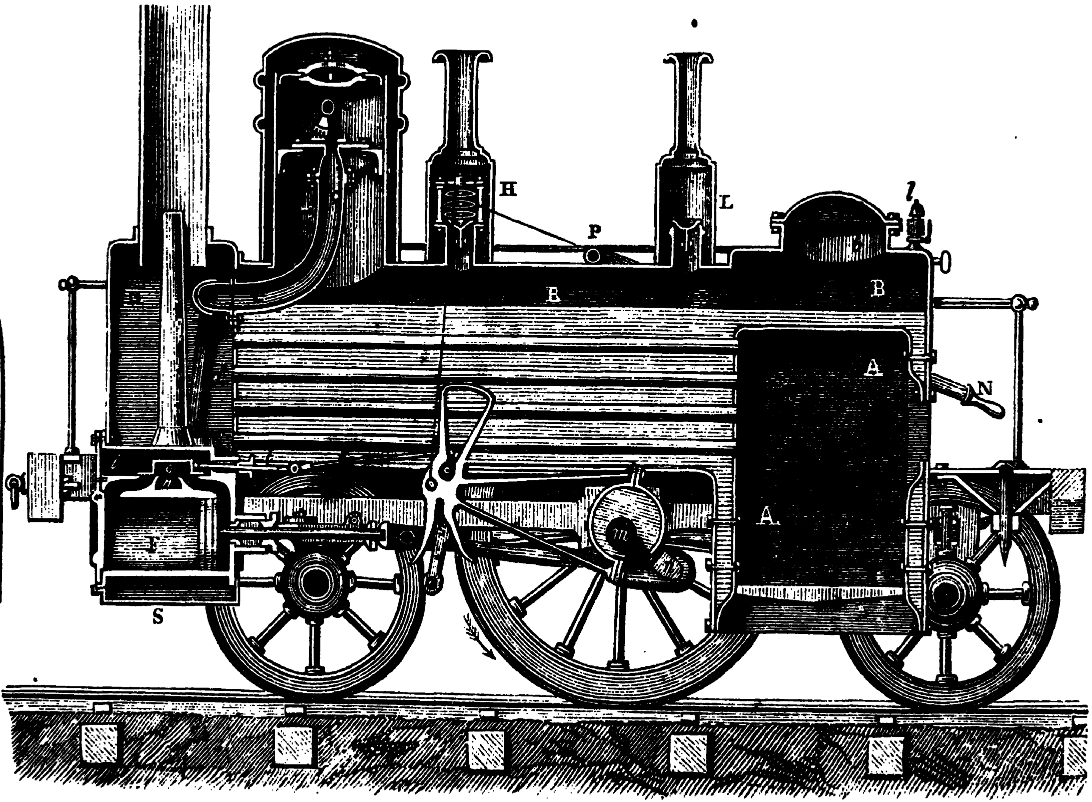


the slide is in this position, the steam will enter the right-hand end of the cylinder, and drive the piston towards the opposite end of the cylinder, whilst the steam passes from the left-hand side of the piston, and thence by the tube *q* into the funnel. If, however, the slide is at the right-hand end of the chamber, the steam contained in the latter will pass by the left canal into the cylinder, and escape through the right-hand canal into the cavity *o*. The piston-rod is fixed in such a manner that it can move only in a straight line. Fastened to the piston-rod is the connecting-rod, which moves the crank *n* around the axle *m*. The middle wheels of the carriage are fastened to the axle *m*, so that the wheels perform an entire revolution every time the piston moves backwards and forwards, and the carriage is likewise propelled to a distance corresponding to the circumference of the wheel.

To the axle *m* is also fastened the excentric disc by which the slide is set in motion. As is seen in the figure, the X-shaped end of the rod, which is fixed to the ring of the excentric disc, grasps the upper extremity of a lever whose fulcrum is seen at *s*. By the motion of this lever the rods *t t*, and the slide which is connected with them, are moved backwards and forwards.

In order to reverse the motion of the engine, it is necessary to raise the lever N. The fulcrum of this lever is at P, where its axis passes obliquely over the whole carriage. Upon each side of the carriage is fastened the arm of a lever, whose directions run parallel to the elongation of N P. From these arms of the levers descend two vertical rods, to the X-formed ends of the rods which are connected with the excentric disc. It is now evident that by raising the lever-arm N, the X on each side of the carriage will be pressed down, so that the rod grasps the lower end of the lever whose fulcrum is seen at *s*. According as the rod grasps above or below, the wheel must necessarily revolve either in the direction of the arrow or in the opposite direction.

H and L represent safety-valves; *l* is a whistle used for giving signals.

[*Note.*—The drawing given on the preceding page merely represents the general construction of locomotives. The engines at present in use on the English railways are furnished with a regulator in the pipe *c*, by which the steam passes from the boiler to the cylinders. The use of the regulator is to modify the supply of steam.—Ed.]

141. Machines, set in motion by steam, were already constructed in the seventeenth century. They were, however, exceedingly imperfect, and it was not till the year 1763 that James Watt constructed the steam-engine, identical, in the most important points, with that now in use. The first successful steam-vessel, on a large scale, was constructed by the American, Robert Fulton, in 1807.

The power of the steam-engine is usually compared with horse-power, and it is assumed that the power of one horse will raise 1,500 pounds to the height of 3·7 inches in a second of time.

The fuel generally employed for steam-engines is coal or coke. A stationary engine of one-horse power requires about 20 pounds of coal in an hour. In the same period of time an engine of

2	horse power requires	31	pounds of coal.
10	,,	100	,,
20	,,	166	,,
100	,,	555	,,
200	,,	1100	,,

The locomotive and steam-boat engines require proportionately a much larger amount of coal.

Transmission of Heat.

142. It is well known that a body, to which a high degree of heat is imparted, gradually loses it, or, in other words, cools down; as also, that a body possessing a low temperature gradually acquires a higher one, when exposed to the influence of heat. Heat may, therefore, be said not to be enclosable in any substance, as it endeavours continually to maintain itself in equilibrium with the surrounding objects; it is, therefore, in perpetual motion.

The transmission of heat takes place in two ways. In the first place, heat may be transmitted through the whole mass of a body by communication from one particle to another, until all have attained an equal temperature. This is transmission by *conduction*. Secondly, heat is transmitted through the air, emanating from bodies in rays, similar to light and sound, it is then called *radiated* heat.

143. All bodies do not transmit heat with equal rapidity through their mass. A piece of iron wire, or a knitting-needle, cannot be held by one end, when the other is heated to redness, without the fingers being burnt, while a shorter piece of wood may burn at one end and be held by the other without the slightest inconvenience. Some bodies are, therefore, good, others are bad *conductors of heat*.

Heavy bodies, such as the metals, are the best conductors of heat, while substances of less density only allow a very slow transmission of heat through their mass. This is particularly the case if the bodies are very porous and loose. Stones, earth, earthenware vessels, and glass are, therefore, numbered amongst the imperfect conductors of heat; while wood, straw, hair, the fibres of plants, and the articles manufactured therefrom, are classed amongst the bad conductors.

Many of the most common phenomena are the results of the various conducting powers of bodies: thus, for instance, water boils sooner in metal vessels than in earthen ones; a piece of red-hot coal soon ceases to glow when placed upon an iron plate, while it will retain its heat for a long time when placed upon wood; the cold sensation produced on touching metal, is likewise owing to the rapidity with which the latter conducts away the heat of the hand.

We dress ourselves in bad conductors of heat, such as woollen cloths and furs, in order to prevent too great a decrease of animal heat by radiation or conduction. For the same reason we employ moss, hay, and feathers for the construction of warm resting-places, and envelope trees and plants in straw, to protect them from the cold.

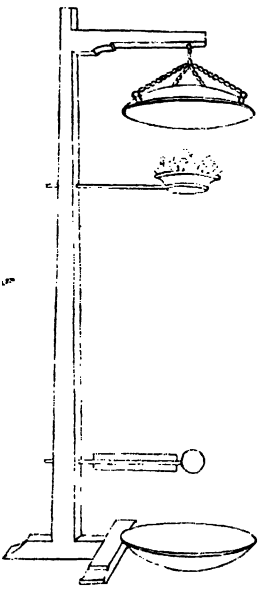
Air and water are likewise bad conductors of heat. The air in cellars and wells maintains nearly the same temperature, summer and winter; and we have already seen, at § 125, that water and air transmit heat rapidly, only because they are set in motion by it. Ice and snow likewise belong to that class of bodies that conduct heat badly. Most winter crops would perish by the frost, if they were not protected by a covering of snow.

144. On approaching a fire, we become sensible of a feeling of warmth—of the rays of heat which emanate from it. That heat reaches us in the form of rays, is proved by placing a screen between ourselves and the fire, when we

shall be protected from its influence. The heat of the sun likewise reaches the earth in the form of rays, which warm the air only slightly in their course; for the upper strata of the atmosphere are always found to be extremely cold.

The rays of heat, like those of sound, are refracted, or *deflected*, when they pass from one portion of matter to another of unequal density; they are also *reflected*, when they encounter solid substances. These phenomena are most strikingly exhibited by *burning-glasses* and *reflectors*.

We shall describe the burning-glass in the chapter on light. Reflectors are concave mirrors of polished brass. In fig. 97, which represents the original contrivance by Sir Humphry Davy, two mirrors of this description are situated opposite each other. All the heat-rays that fall on the surface of a reflector, in a direction parallel to its axis, are reflected thereby in such a manner, that they meet at a certain point in front of the mirror, at the point indicated by the bulb of the thermometer. The total amount of heat-rays collected by the reflector are united in this one point; it is, therefore, called the focal- or burning-point. If an object that emits heat be placed in the focal-point of a concave mirror, the whole of the heat-rays that fall upon the latter are reflected in a parallel direction.


97.

These properties of reflectors have been proved by the following experiments. Two mirrors are placed opposite each other, as in fig. 97, and in the focal-point of one of the mirrors is placed a red-hot iron ball, or a ladle filled with red-hot coals. If we now place a piece of tinder in the focal-point of the other mirror, which may be removed from 18 to 20 feet, the tinder will be inflamed, as all the rays which proceed from the red-hot body are collected by one of the mirrors, and thrown in a parallel direction to the other mirror, which collects them in its focal-point, and by this means sufficient heat is produced at this point to ignite inflammable bodies. A thermometer, held slightly out of the focal-point, or in any place between the two mirrors, will show that the heat-rays produce no appreciable change of temperature at any other point than that above named.

The temperature of the focal-point depends upon the size of the reflectors and the temperature of the source of heat. Reflectors have been constructed by means of which a temperature may be obtained by the collection of the sun's rays at the focal-point, sufficient to melt and ignite substances, upon which the fiercest fires are scarcely capable of producing the same effect.

The velocity of the rays of heat is equal to those of light, which travels at the rate of 195,000 miles in a second.

145. The relations exhibited between different bodies, and the heat-rays falling upon them, are exceedingly various. Some bodies allow all the rays of heat to pass through them, without retaining or absorbing a single particle:

this is the case with air, and also with several solid bodies, as, for instance, rock-salt. These are, however, exceptions to the rule, as all other solids retain a greater or smaller amount of the heat-rays which fall upon them.

As a general rule, the denser the body, and the lighter its colour, the smaller is the amount of heat which it will absorb, and *vice versâ*. Thus lamp-black will retain nearly all the heat-rays that fall upon it, while polished silver or iron reflect them almost completely. If one thermometer be covered with white cloth, and another with black, and both are equally exposed to the sun, the one in the black covering will indicate a higher temperature than the other. Snow will melt more rapidly when covered with a black cloth than it will under a white covering. It is intelligible from this, why white or light coloured dresses should be preferred in summer, and dark ones in winter.

These two classes of bodies are likewise opposed to each other in their *radiating* power. Dense bodies only possess this power to a slight degree, while it is much greater with porous bodies. Thus, a hot liquid, as tea or coffee, will cool much more slowly in a bright metallic vessel than in a vessel of earthenware, which is coated with lamp-black.

Latent or Combined Heat.

146. We have seen in § 130, that water, when it has once been heated to the boiling point, cannot attain a higher temperature, even if continuously exposed to a greater heat. In that case a portion of the heat passes over continually to the vapour, and the thermometer will indicate 100° C. (212° F.), whether it be immersed in the water or the steam. If snow or ice, the temperature of which is exactly 0° C. (32° F.), be placed in a vessel on a stove, the water produced by its melting will likewise indicate a temperature of 0° C. (32° F.). All the heat imparted in both cases appears merely to serve for the conversion of solid water into liquid, and of the latter into steam, without the water produced by melting indicating a higher temperature than the snow, or the temperature of the steam being higher than that of the boiling water.

Bodies are, therefore, capable of absorbing heat without altering in temperature; they are, however, converted thereby from the denser to the lighter state. The heat thus absorbed, that is, rendered imperceptible to the sense of feeling, is said to be *latent* or *combined*. The steam produced at 100° C. (212° F.) is consequently water of 100° C. (212° F.) + latent heat.

In all cases when a body passes over from a denser to a lighter condition a certain amount of heat is always absorbed or rendered latent. This heat is abstracted from the surrounding objects, the temperature of which is consequently reduced. If, for example, water be poured on the ground, on a hot summer's day, it will pass over into vapour, abstracting thereby a large amount of heat from the surrounding air and earth, which will be felt to be much cooler in consequence. If two thermometers be suspended together, the bulb of one being moist and the other dry, the former will indicate the lower temperature, as the water, evaporating on its surface, abstracts a portion of its heat.

147. Gaseous bodies, however, in their transition to the fluid, or from that to the solid state, part with their latent heat. This liberation of heat generally occurs under circumstances where it cannot be well perceived; there are, however, a few very striking examples of the conversion of latent into sensible heat, one of which is the disengagement of heat in pouring water over unslacked

lime: the nature of this experiment will be more fully explained in the section on Chemistry.

148. On heating equal weights of different substances of the temperature of 0° C. (32° F.) to + 1° C. (33°·8 F.), it will be observed that the quantity of heat required is very different. If water, oil of turpentine, iron, and mercury be employed for the experiment, it will be found that the quantities of heat required by these bodies to raise their temperatures from 0° to + 1° C. (32° to 33°·8 F.) stand in the relation of $1 : \frac{1}{2} : \frac{1}{8} : \frac{1}{33}$. Oil of turpentine requires, therefore, only one-half, iron one-eighth, and mercury only one-thirty-third of the heat required by water to attain the same temperature. If two vessels, perfectly similar, are procured, the one containing one pound of water, and the other one pound of oil of turpentine, both of equal temperature, it will be necessary, in order to heat them both to an equal number of degrees, to place under the vessel containing the water *two* flames of equal size to the *one* that is required by the oil of turpentine.

The relative quantities of heat required by different bodies to attain an equal increase in temperature are termed their *specific heats*. For comparative purposes the specific heat of water is fixed at 1.

It may be concluded from these statements that as every body possesses a peculiar density, so likewise all bodies contain a certain quantity of heat that cannot be indicated by the thermometer, and on the amount of which depends their capacity for absorbing a farther quantity, or as it is termed, their *capacity for heat*.

149. The *distribution* of heat on the surface of the earth is very unequal; various parts thereof are well known to possess temperatures varying very much from those of other parts. It has been already mentioned that the sun must be considered as the principal source of the heat of the earth. The sun's rays do not, however, fall in equal directions on every point of the earth's surface: in the vicinity of the equator their direction is nearly *vertical*, while in the countries approaching the poles they fall obliquely; in fact, their direction becomes more oblique in proportion to the distance from the equator. All heat-rays that fall upon a body at an angle are, however, reflected at the same angle, and only those that fall perpendicularly are perfectly absorbed. Hence the temperature at the equator is much higher than at any other part of the globe: in consequence of this difference of temperature, the earth has been divided into a torrid or tropical zone, the two temperate, and the two cold zones or polar regions.

The difference between summer and winter in the temperate zones is occasioned by the greater length of the days in the first-named season, and by the sun's rays reaching the earth in a direction more approaching the perpendicular than at any other time. In the winter, when the sun is nearer to the earth by about four and a half millions of miles than it is in the summer, the rays fall in a very oblique direction.

150. By the *mean temperature* of a day is understood the mean of the highest and lowest temperatures observed throughout its duration. To arrive at the correct number, observations should, properly speaking, be made from hour to hour, or even at still shorter intervals. Experience has shown, however, that the mean temperature of a day may be arrived at with sufficient accuracy by observing the thermometer in the morning at 7 o'clock, again at

noon, and at 10 in the evening, and calculating the mean of these observations. The mean temperature of the day furnishes, by calculation, that of the month, and that of the year is obtained from the temperature of its twelve months.

It is evident that the mean temperature of various places must be exceedingly different, and by way of illustration we may subjoin a few examples:—

Place.	Latitude.	Mean Temperature.		Place.	Latitude.	Mean Temperature.	
		C.	Fahr.			C.	Fahr.
Melville Island -	74°	−18°	0°	Vienna - - -	48°	10°·1	50°·2
St. Bernards -	45	− 1	30·2	London - -	51	10 ·4	50 ·7
St. Petersburg -	59	+ 3	37·4	Paris - - -	48	10 ·8	51 ·4
Königsburg - -	54	6	42·8	Constantinople	41	13	55 ·4
Berlin - - -	52	8	46·4	Rome - - -	41	15	59 ·0
Munich - - -	48	8	46·4	Canton - -	23	21	69 ·8
Frankfort-on-the-Maine - -	50	9	48·2	Calcutta - -	22	28	82 ·4

Although the greater number of the above temperatures confirm the rule, that the temperature of countries increases in proportion to their vicinity to the equator, yet we find several exceptions to this among the numbers quoted. These arise from the great influence exercised over the temperature by the nature of the earth and of the surrounding objects. Thus, countries under the same latitude will be found to be colder the higher they are situated, the more they are exposed to cold currents of air, and the farther they are distant from large masses of water. Low countries, sheltered from cold winds by chains of mountains, and particularly with barren surfaces, are the hottest. The temperature of land is much decreased by a luxuriant vegetation, partly because plants radiate a large amount of heat during the night, and partly because the evaporation of water occasioned by them renders a large amount of heat latent.

Comparatively small tracts of land, nearly or entirely surrounded by large masses of water, as England, Italy, and the smaller islands, possess most uniform temperatures, partly because the water requires a large amount of heat for the formation of vapour, and partly because it radiates much less heat during the night than does the land. The temperature of England is, indeed, much more uniform than that of Germany; and although the mean temperature of the two countries is the same in many parts, yet, on the Continent, the summers are hotter and the winters colder than on our island. Hence many plants live through the winter here that would perish in Germany, while, on the other hand, grapes and other kinds of fruit do not ripen here as they do abroad, because the heat of the sun never attains a sufficient power.

III. Light.

"Joyful be those
Who breathe in the rosy light."—*Schiller.*

151. The cheering phenomena of light arise from various allied causes, and in this sense we shall speak of the different sources of light. As such we shall consider:—1. The sun and the fixed stars. 2. Heat, since all objects as soon as they are exposed to a certain temperature appear luminous, it being imma-

terial whether it be the result of mechanical or chemical action (the latter, however, is most common). 3. Electricity. 4. Many animals of the lower classes which possess the property of appearing luminous, and of which the glow-worm is the most familiar example. Many plants, particularly the Rhizomorpha, frequently found in mines, likewise possess this property in a small degree. 5. The decay of animal matter, particularly of fish, and the dry rot of wood, which give rise to a feeble luminosity. The most important of all these sources of light is the sun. Next to this, the light produced by the chemical process of combustion exercises the greatest influence.

In all other cases besides those above mentioned, when light is observed to proceed from any object, it does not originate with the latter, but has been previously communicated to it from some of the above sources. Bodies are, therefore, *luminous* or *non-luminous*. The light of the moon is derived from the sun, the former being non-luminous, like the earth and most other bodies.

152. Light occurs so frequently in company with heat, and corresponds with the latter in so many of its properties and in so remarkable a manner, that they have been considered by many as inseparable, or more properly speaking, as one and the same thing in different degrees of intensity. They may, however, be distinguished and separated; for there are many powerful kinds of light, for instance, that of the moon and of several luminous insects, that are unaccompanied by any heat, or at any rate by any perceptible amount, and, on the other hand, many substances may be found that will retain a large amount of heat without becoming luminous.

153. Light is distributed only in rays, proceeding from the luminous body in all directions. The velocity with which light travels is extraordinary: it passes over 195,000 miles in a second of time, and occupies, therefore, only eight minutes and thirteen seconds in travelling from the sun to the earth.

The rays of light, when they meet with substances, exhibit a similar behaviour to those of sound and heat, the resulting phenomena, however, being naturally different in appearance. We will notice three cases in particular.

(1.) The rays of light are more or less perfectly intercepted or *absorbed* by the bodies which they meet.

(2.) They are thrown back or *reflected.*

(3.) They pass through bodies.

154. When all the rays of light falling upon a body are absorbed, they disappear altogether, or become invisible: the body that has thus absorbed them appears perfectly *black.* A body of this description does not take up light by continued exposure, as it might heat, in such a manner as to distribute it again in any way. Thus, a want of light or *shadow* is produced on the side of the body opposite to that which is exposed to the rays of light. Lamp-black is the substance that most completely absorbs light.

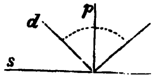
By far the greater number of bodies partly reflect the light as it falls upon them, and absorb another portion. Dense bodies, particularly bright metals, reflect light most perfectly. The reflecting power of other bodies decreases proportionately to their porosity, and consequently bear an inverse ratio to their density. There is likewise a want of light, or shadow, produced behind those bodies that reflect light.

All bodies become visible only by their reflecting the rays of light; it is highly important, for the proper comprehension of all phenomena of vision, to

bear in mind continually, that rays of light proceed in all directions from *every visible point* of a body, and that the body is rendered visible to us by one of these rays reaching our eyes.

155. Such bodies as reflect light perfectly are called *mirrors*. Without regard to the material of which they consist, we distinguish—1, *plane* or common mirrors; 2, *concave* or hollow mirrors; 3, *convex* or raised mirrors.

A plane mirror *s s′* fig. 98, reflects the rays that fall upon it in such a manner that the incident ray *r i* forms the same angle with the perpendicular *p i* as the reflected ray *i d*, whence it follows that the rays diverge from a mirror in such a manner as though they issued from one point, situate as far behind the surface of the mirror as the luminous point lies before it. Hence the image appears to be situated as far behind the surface of the mirror, as the object is placed before it; and it s reversed in such a manner that the left side of the object becomes the right side of the image, and *vice versâ*.



98.

156. The common mirror consists of a glass plate, possessing surfaces as smooth and parallel as possible, one of which is coated with an amalgam of tin and mercury.

Mirrors, the surfaces of which are not parallel, and which are otherwise uneven and not clear, produce distorted images, and, therefore, cannot be used.

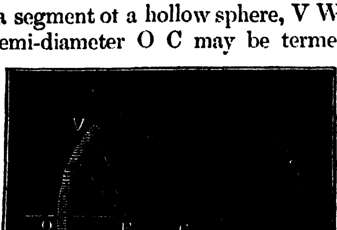
If two mirrors be placed opposite and parallel to each other, the image of one mirror will be seen in the other, and an endless number of images is thus obtained. If, however, the mirrors are so placed as to form an angle, the number of mutual reflections will be diminished, and indeed proportionately to the extent of the angle formed by the mirrors.

The construction of the *kaleidoscope* is based simply on the multiplication of an image by two mirrors inclined towards each other.

The mirror has not only become an indispensable article of furniture, by the ordinary uses made of it, but has also been applied in the construction of many optical instruments.

157. A *concave mirror* may be represented by a bright soup-ladle or the reflector of a lantern. The important applications of this mirror render a slight study of its properties necessary.

A concave mirror may be considered as a segment ot a hollow sphere, V W, fig. 99. The central point C, and the semi-diameter O C may be termed respectively the *geometrical centre*, and the *radius*. The point F in the centre of the radius is called the *focus*, and the line passing through the centre C, and the focus F, is termed the *optical axis*. The point O of the mirror which is met by the prolongation of the axis is called the *optical centre*.



99.

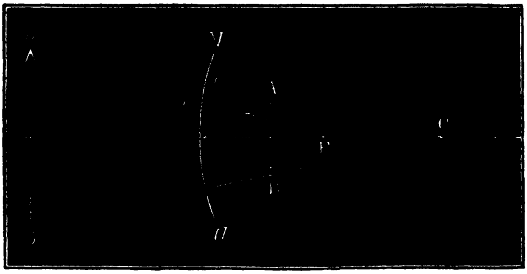
All rays of light that fall *perpendicularly* upon this mirror are reflected in the same direction, so that they pass through the centre of C. All rays that are parallel

with the optical axis are reflected by the mirror towards the focus F, and are there collected (comp. § 144).

158. On approaching the concave mirror to any object, various images are obtained, according to the distance between the two. If an arrow, for example, be placed between the focus and the mirror, a *magnified* image thereof will be obtained, appearing, however, to be situated at the back of the mirror, as was the case with the plain mirror. On placing the arrow between the focus and the geometrical centre of the mirror, a *magnified* image will be likewise produced, appearing, however, to be situated in front of the mirror.

Let us endeavour to account for these phenomena by the aid of fig. 100.

If the ray A n passes from the object A B at right angles upon the mirror, it will be reflected in the direction n A C; the ray A e proceeding parallel with the axis of the mirror will be reflected towards the focus F. These two reflected rays will never meet in front of the mirror. If, however, we imagine their direction to be prolonged at the back of the mirror, they will intersect each other at the point a, and the object at A will appear to the eye to be situated at that point. The whole of the rays of light passing from A B will be similarly reflected, and thus the magnified image a b is produced at the back of the mirror.



100

In fig. 101 where the arrow is placed between the focus and the geometrical centre, the ray A u falling perpendicularly on the mirror is reflected in the same direction, whilst the ray A c, that is parallel with the axis of the mirror, is reflected to the focus F. The point A of the object A B must, therefore, appear to occupy that position where, by the prolongation of the two reflected rays, they appear to intersect each other, which is the case at a, as seen in the figure. Rays falling on the mirror from other points of the object would be similarly reflected, and thus the magnified but reversed image would appear situated in the air in front of the mirror.

101.

It may easily be proved that this image really is in the air, for on holding a sheet of white paper at a b, the rays will be intercepted, and the image will be distinctly visible on the paper.

159. The concave mirror has found a most important application in the

telescope: the so-called *reflecting telescopes* have been constructed by which enormous magnifying effects are produced, such as those obtained with Herschel's celebrated gigantic telescope, which measures five feet in diameter. This kind of telescope has of late met with few applications, as its construction and management are attended with great difficulties. It has been already stated in our chapter on Heat, that concave mirrors may be used as reflectors. They afford likewise excellent means for increasing the power of light, as all rays thrown upon a concave mirror by a light placed within its focus, are reflected in a parallel direction; hence this mirror has been applied to lanterns, magic-lanterns, and lighthouses.

160. The *convex* mirror is of less interest than the former. It is also called the *dispersing* mirror, as all the rays of light that fall upon it are reflected in a diverging direction. It produces *diminished* images of objects, such as may be observed in polished raised metal buttons, or large glass globes, &c.

Refraction of Light.

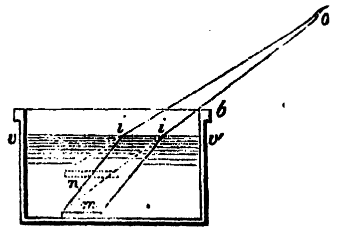
161. It has been observed at § 153, that some bodies allow of the passage of rays of light through their mass. Such bodies are—air, water, glass, and, in fact, all such as are called *transparent*. It is well known that all bodies do not possess this property to an equal degree. There are semi-transparent and translucent bodies, and others that are only translucent when their mass is extremely thin. Thus, even that dense body, gold, is translucent, when beaten out into thin leaves. In the study of light, however, only those bodies are of importance that are perfectly transparent.

As long as the rays of light pass through the same medium or kind of matter, for instance through the air, their direction remains perfectly straight and unaltered. If, however, a ray of light fall upon a transparent body of greater or less density, it will no longer continue its motion in the original direction, but will follow another which forms a greater or smaller angle with the first.

In such a case the ray of light is said to be *broken* or *refracted*, and the angle denoting the amount of refraction is termed the angle of refraction.

The more common phenomena of refraction are observed when light passes from the space of the universe into the denser atmosphere of our earth, or when it passes from air through water or glass.

It is a well-known fact that a straight stick, when partly immersed in water, appears to be broken at the point of immersion. This is in consequence of the rays of light that pass from the stick to the eye following a different direction when they emerge from the water. Thus, we should not be able to perceive the object *m* in the vessel *v v′*, fig. 102, if the latter were empty, and the eye were situated at *o*. When, however, water is poured into the vessel, the rays passing from *m* to *i i* are refracted on emerging from the water, and the object will now appear to the eye to be situated at *n*, much higher, therefore, than its real position. Hence, any objects lying in water appear to be nearer its surface than is really the case.



102.

162. On allowing a ray of light to pass through a thin body with two parallel surfaces, it undergoes scarcely any perceptible alteration. This is observed in window-panes, through which objects appear in their true position.

The case is, however, very different, if the surfaces of the body, through which the light passes, are not parallel.

In experiments on this subject, curved glasses are always employed which have received the name of *lenses*, as some of them possess the form of a lentil. They are of great importance in the construction of telescopes and powerful microscopes.

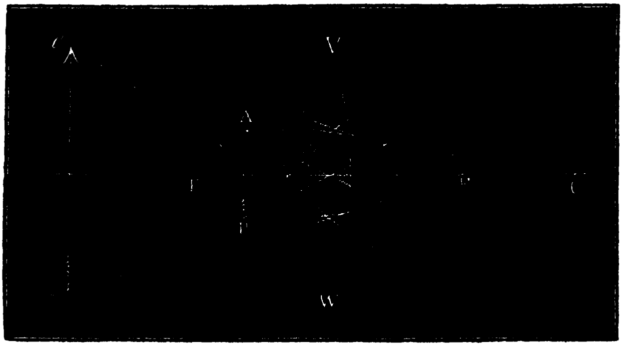
163. Lenses, like mirrors, are distinguished into those that collect the rays of light and those that disperse them.

The collecting lenses are always thickest in their centre; they are called *double convex lenses.* These likewise contain a focus, a geometrical central point, and an axis, like the convex mirror: the kind of image obtained by this lens is dependent on the position of the object. All rays passing through the central point of these lenses remain unaltered, while those whose direction is parallel with the axis are refracted by the glass in such a manner that they unite at one external point.

The focus of a lens may easily be found by allowing the rays of the sun to fall perpendicularly on one side of it, whilst a sheet of paper is held on the other. A bright ring of light will be observed on the latter, diminishing or increasing in size according to the distance of the paper from the glass. If the former be held in such a manner that the ring of light is reduced to a dazzling luminous point, it is then situated in the focus of the glass. The heat-rays that accompany those of light are likewise united at this point, which is found, in consequence, to possess a high temperature, frequently sufficient to ignite substances. The double convex lens has hence been also called the *burning-glass.*

We will now proceed to examine the phenomena produced by convex glasses.

Fig. 103 represents a lens V W, and an object A B, situated between the glass and its focus F. The ray A c is now so refracted as to appear to

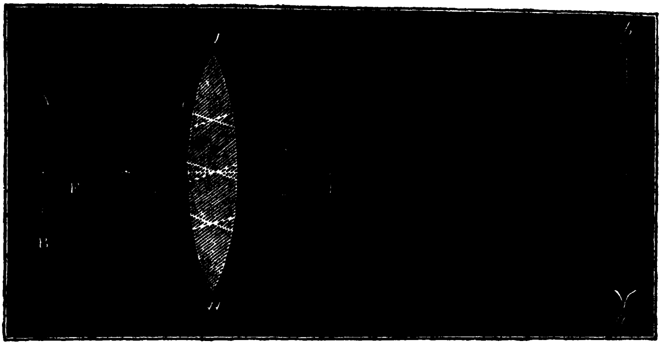


103.

the eye, on the other side of the lens, to come from a. The ray coming from B

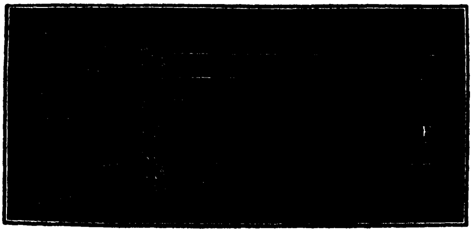
behaves in a similar manner; so that a magnified image of the object is obtained on the same side of the lens.

If, however, the object is farther removed from the lens than the focal-point F, as in fig. 104, an inverted magnified image of the object is obtained on the opposite side of the lens, and may be allowed to fall upon paper.



104.

164. The *concave lens* may be also called the hollow lens, as it is spherically hollowed out on both sides (fig. 105). Its properties are widely different from those of the convex lens, all the rays that fall upon it in a direction parallel with its axis being so refracted that they diverge, on emerging from the lens, as though they issued from the point F.



105.

It *converging* rays fall upon a concave lens, they will emerge either in a parallel direction, fig. 105, or, if they converge only slightly, as in fig. 106, they will diverge on passing out.

106.

Concave lenses are hence called *diverging* glasses.

165. A very great importance is given to polished glasses by the properties we have just described. Thus the double convex lens by itself is the magnifying glass in its most simple form; it passes under the general name of lens, and is employed by watchmakers, engravers, mould-cutters, &c. It is likewise indispensable to botanists and anatomists. By an appropriate combination of lenses, microscopes are constructed, capable of furnishing images of the objects observed through them, magnified from 100 to 1,000 times. By means of these instruments, myriads of minute living creatures have been discovered, of the existence of which no conception was previously entertained, and the most important discoveries have been made regarding the structure of plants and the larger animals.

These glasses have, however, not only served to increase the visual powers of the human eye with regard to objects in its vicinity, but they have become the key to the infinite space of the heavens, and far-distant worlds have been brought by them within the range of our vision. Such combinations of lenses as serve for observations in the distance are termed *telescopes:* the general principle of their construction is, that the rays of light proceeding from a distant object are collected by a very large lens, termed the *object-glass*, or by a large concave mirror, and the image thus obtained is magnified by a second lens or the *eye-glass*.

It is to telescopes of this description that we are solely indebted for our knowledge of the wondrous construction of the moon's surface, of the satellites of Jupiter, of Saturn's ring, and of many other important astronomical phenomena. The telescope is likewise indispensable to land-surveyors, mariners, military men, &c.

Finally, we have to call attention to a particular application of the images produced in the air by lenses, as in fig. 104. If an image of this description be allowed to fall upon a white surface, in a dark chamber (camera obscura), it may easily be traced thereon by means of a pencil. If the object be very powerfully illumined by a double convex lens, a highly-magnified image may be obtained on a white surface: such images as these are exhibited by the *magic lantern*, and more particularly by the *solar* microscope.

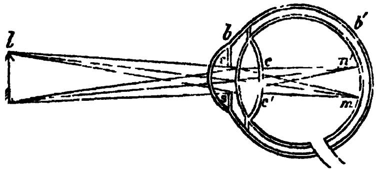
The art of preparing lenses of glass was first practised in Holland. They were, however, at first only used for spectacles, until towards the close of the 17th century, the microscope was invented by Leuvenhoek. The invention of the telescope is ascribed to Gallilei. Both instruments have been gradually very much improved, the latter particularly by Keppler, Herschel, Newton, Fraunhofer, and several others.

VISION.

166. Of no other organ of sense is the purpose of each individual part so accurately known as of the *eye*. It is, indeed, nothing more than a tolerably-simple optical instrument, which may be most easily comprehended by a careful examination of the eye of an ox. On cutting one open, and removing the so-called *crystalline lens*, which consists of a gelatinous substance, it will be found to behave itself exactly like a convex lens cut out of glass.

The Physicist views the apple of the eye as a small round chamber (camera obscura), with a black interior coating, surrounded by membranes, and filled with a perfectly-transparent gelatinous substance, which is called *humor vitreus*.

The front part of the membrane enclosing the eye, the *tunica sclerotica*, is transparent, and more strongly curved than the rest of the globe: it is called the *cornea*, and forms, with the clear liquid it contains, the *anterior optic chamber*, *b*. The rays of light pass into the eye from any object, for instance, from $l\ l'$, through a small round opening *s s*, called the *pupil*; they undergo a refraction by the crystalline lens $c\ c'$, by which an image of the object is formed on the



107.

retina $m\ m'$, a net-like membrane, which is situated at the back of the eye: we become conscious of this image through the *optic nerve*.

The rays of light proceeding from the object $l\ l'$, are first refracted in the anterior optic chamber *b*, and afterwards again undergo refraction by the lens $c\ c'$, by which a diminished image of the object is produced between $m\ m'$.

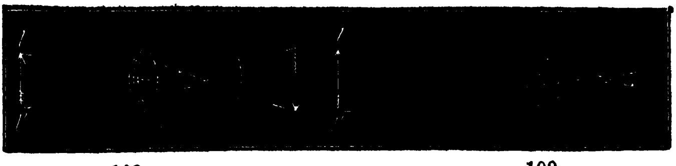
That this is really the case may be shown with the eye of an ox, namely, by removing carefully the back portion of the membrane in scales or layers, so that it becomes thin and translucent, and then holding an object, for instance a burning candle, before the pupil of the eye; a small image of the candle will then be distinctly visible on the retina.

It is hence explicable why *inverted* images are obtained of all objects presented to the eye, why, for example, we see in fig. 107 the point *l* at *m*, and the point l' at m', and why, in the experiment with the eye of an ox the diminished image of the candle appears inverted.

As we are accustomed from our earliest youth to observe simultaneously with the senses of vision and feeling, the observation made by the former is immediately rectified by the latter.

It is clearly proved by children and by persons who are born blind and receive their sight in later years, that we only arrive at a correct conception of the situation of objects and of distance, by our sense of feeling and by the movements of our body.

167. Every one, in reading a book, holds it at such a distance from his eyes, as will enable him to see it most distinctly. This distance is called the *distance of distinct vision*, and it generally amounts to eight or ten inches in a perfectly sound eye. At this distance, a sharply-defined image of every letter falls exactly upon the retina, the rays proceeding from every point of the object being so refracted in the eye that they reunite at one point of the retina, as seen in fig. 107, and then produce a perfectly-distinct image. If we assume the eye to retain the exact arrangement exhibited in the above figure, and



108. 109.

approach the object closer to the eye, the rays proceeding from one point of

the former will diverge so strongly, that they will not become sufficiently refracted by the eye for the production of a distinct image on the retina. Indeed, the image must fall at the *back* of the retina, only an *indistinct* image being then produced (fig. 108) If the object be removed beyond the distance of distinct vision, the rays proceeding from it will converge to such an extent as to be united before they arrive at the retina, and in this case an indistinct image is likewise produced (fig. 109).

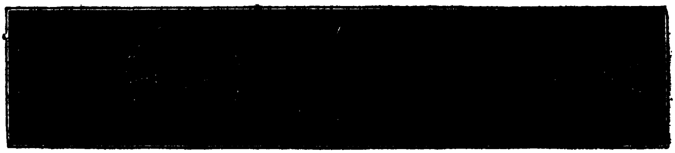
Hence every object that is closer to, or more remote from, the eye than the distance of distinct vision, must appear indistinct. This is, however, not the case with a perfectly sound eye, any object at a distance is distinctly visible to it, and will remain so, when approached, to a certain limit. The reason of this is, that the arrangement of the refracting portions of the interior of the eye is not unalterable, but may be modified for distant or close vision. If, on viewing an object close at hand, the tunica sclerotica, or fore part of the eye, becomes more strongly curved, it will receive a greater refracting power, whereby the image is made to fall on the retina. When the eye observes remote objects, this portion of the eye becomes flattened, and the distance at which the rays unite, in front of the retina, is thereby diminished.

This capacity of the eye to suit itself to viewing distant or contiguous objects, is called its power of *adaptation* or *accommodation*. This power is, however, not common to all eyes By frequently or continually looking at objects too close, particularly in one's youth, the forepart of the eyes will soon acquire a *permanently-increased* curvature, and they will thereby lose their power of adapting themselves to distant objects, which they will therefore see only indistinctly this defect in vision is called *short-sightedness*. The eye is *long-sighted* if it is incapable of adapting itself to view objects that are closer to it than the usual distance of distinct vision, which is eight or ten inches.

The defective vision of a short-sighted person is, therefore, the result of too powerful a refraction of the rays of light by the eye, while with a long-sighted person the reverse is the case. Both defects may be artificially remedied, by employing lenses, which, if convex, will assist in collecting the rays, and if they are concave will assist in their dispersion.

168. *Spectacles*, therefore, afford us means of properly adjusting the refraction of the rays of light, so as to produce a well-defined image on the retina a long-sighted person must be supplied with spectacles with convex lenses, while short-sighted people require concave spectacles.

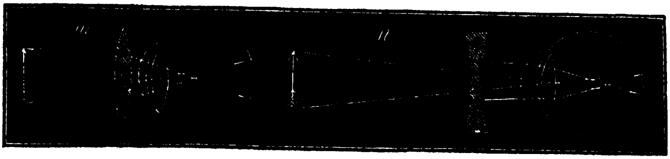
Fig. 110 represents a long-sighted, and fig 111 a short sighted eye, neither of which is capable of producing a distinct image of the object $l\ l'$, as, in the



110. 111.

one case, it will fall at the back, and, in the other, in the front of the retina. If these eyes are, however, supplied with the appropriate spectacle-glasses *m*

and n (figs. 112 and 113), the convex lens will effect a greater refraction of the



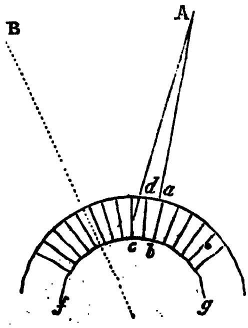
112. 113.

rays, and the concave a less-powerful refraction, so that in both cases the image of the object will fall exactly on the retina, and will consequently be well defined.

It is evident that the concavity or convexity of the spectacle-glasses must be regulated according to the magnitude of the defect in the vision.

A person may become blind by an injury sustained by the optic nerve: this kind of blindness is incurable, and is called the incurable cataract, or *amaurosis.* Blindness is more frequently occasioned by *common* cataract, in which case the lens of the eye becomes dim or opaque. This disease may be cured by making, with a steady and practised hand, an incision at one point in the membranes of the eye, by means of sharp and pointed instruments, and then either extracting the lens through the pupil, or pressing it down, so that light may be able to pass into the chamber of the eye. After the operation, the eye is supplied with spectacles containing very powerfully refracting double-convex lenses, in order that the dispersed rays of light falling on the eye may be refracted and fall together on the retina.

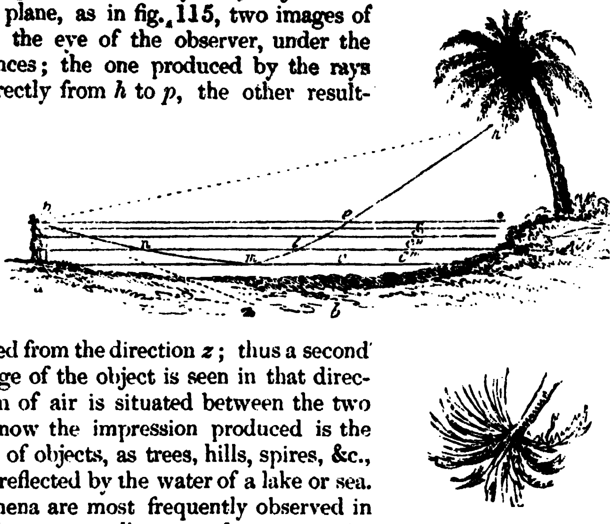
The eyes of the higher orders of animals, namely, the mammalia, birds, amphibious animals, and fishes, correspond with the human eye in the most important parts of their structure. Of the more imperfect animals, some possess no eyes, and others have eyes of a peculiar construction (fig. 114). A great number of small hollow cones *a b c d*, stand rectangularly upon the convex retina, *f g*, and through which the rays of light, proceeding from the various points of an object, fall upon the retina. These animals can only see contiguous objects, which appear to them as an object does to our eyes when viewed through wire-work. Each small cone is covered at the upper extremity with a transparent membrane; and an eye of this description presents to us the appearance of a hemisphere, with numerous small surfaces, amounting to from 12,000 to 20,000. All insects, for instance the common flies, have eyes of this description. Many, however, in addition to these plane-surfaced eyes, have lens-eyes, as is the case with spiders.



114.

169. Under certain circumstances, Nature herself gives rise to the conditions required to produce remarkable *reflections* of objects in the air, and to which phenomena the names *air pictures*, *fata morgana*, and *mirage* have been given.

For the production of these phenomena, large planes are necessary, over which extends an exceedingly calm stratum of air, so that, after sunrise, the lower portions rise only very gradually as they become warm, and mix with the denser upper portions. If any lofty objects are situated on the plane, as in fig. 115, two images of these will reach the eye of the observer, under the above circumstances; the one produced by the rays that proceed directly from h to p, the other resulting from a ray, proceeding from h, being refracted by the less dense strata of air, c, c', c'', c''', to such an extent that it appears to proceed from the direction z; thus a second but *inverted* image of the object is seen in that direction. A stratum of air is situated between the two images, so that now the impression produced is the same as if a row of objects, as trees, hills, spires, &c., were visible and reflected by the water of a lake or sea.



115.

These phenomena are most frequently observed in the deserts of Egypt: travellers are often most painfully disappointed by the sudden disappearance of what seemed to them refreshing waters in the midst of the scorching sand.

Some varieties of these reflections have also been observed, although but rarely, over seas and other places.

Halos round the moon, as also *mock suns* and *moons*, may be seen occasionally, when these bodies are viewed through very thin strata of clouds, which cover the heavens. These phenomena are likewise considered as resulting from the refraction and reflection of light.

Colours.

170. A ray of light, when directed, by means of a mirror m, fig. 116, into a darkened room, through an opening o in the window shutter, will produce on the opposite wall t of the room a round white image g. If, however, the ray be received upon a triangular piece of glass (a so-called *prism*, of which p is a section), on its immediate entrance through the opening, it will not merely diverge considerably from its original path, but will likewise produce an elongated streak of light upon the wall, between r and u,

116.

composed of beautiful colours, the lower end at *u* being *violet*, which is followed successively by stripes of *indigo-blue*, *blue*, *green*, *yellow*, *orange*, and *red*. These are the same colours, and arranged in the same order, as those observed in the rainbow; they are called *prismatic* or rainbow colours, or colours of the solar spectrum.

The white solar light is, therefore, not only refracted by the prism, but also *decomposed* or dissected into seven luminous rays of different colours. The white rays are, therefore, called compound or *mixed* light, because they are composed of the *seven* simple rays. The possibility of decomposing light is based upon the circumstance, that its component parts possess *various degrees of refrangibility*. If the solar spectrum be examined, it will be seen that the red light is situated nearer than the violet light to the position which the non-refracted spot of white light would occupy; the former possesses, therefore, the least, and the latter the greatest refrangibility. The difference in refrangibility arises from the unequal length of the waves of light composing the simple rays, it being analogous to the difference in sound, caused by the unequal length of the sound-waves.

If the seven coloured rays proceeding from the prism be collected by means of a convex lens, they will be reunited at its focal-point to *white* light. This phenomenon may be observed by simply pasting in a circle upon the upper part of a peg-top, pieces of paper of equal size and various colours, resembling as much as possible the prismatic colours, and then spinning it; the impression made upon the eye by the various colours will become mixed, and the variegated upper surface of the top will appear white.

Those bodies, therefore, that refract all the rays of light in their original mixture, are *white*, while those that absorb the rays are *black*. There is, however, scarcely a body existing that possesses one or other of these properties in its full extent, hence result the various shades from white, through gray, to black.

There exist likewise bodies, the particles of which are so arranged that they only check the vibrations of certain waves of light, while they refract the remaining waves unaltered. Thus, a *red* body absorbs all the coloured rays of the white light that falls upon it, with the exception of the *red* rays, which it reflects. All other colours of substances, such as blue, green, yellow, &c., are accounted for in the same manner.

171. Many substances only appear coloured when they are seen in large masses; glass or ice, for instance, appear colourless when in thin layers, while they have a green or blue appearance when viewed in larger masses. Even the air, when viewed in a mass of the height of the atmosphere, has a beautiful blue colour: assuming the absence of the atmosphere, the space of the heavens would appear black. Indeed, the air, when viewed from many high mountains, appears dark blue, because the black of the universal space above, penetrates through the less dense and high stratum of air. On level ground even, the air appears to us darker over our heads than at the horizon, as, in observing the latter, we have to look through a mass of air of far greater extent than that situated over our heads. The blue appearance of distant hills is imparted to them by the large mass of air, situated between them and our eyes.

The *red* and *yellow* colour of the heavens, known by the name of *evening* and *morning red*, is ascribed to the property possessed by the aqueous vapour

in the air, particularly when it passes over from the state of fog into real vapour, of allowing the passage of red and yellow light only. This production of vapour generally takes place in the morning or evening.

The Rainbow.

172. This phenomenon of Nature is so remarkable for the splendour of its colours, that it requires our particular notice. Though rain and sunshine are pretty generally known to be the necessary conditions for the production of the rainbow, the precise explanation of its formation cannot be given in a few words; we shall, therefore, confine ourselves here to an endeavour to lead to the proper comprehension of its nature.

A comparison of the rainbow colours with those of the solar spectrum produced by the prism (§ 170), which will be found to correspond with them in shade and arrangement, must lead to the conclusion that the formation of the rainbow is owing to the refraction and decomposition of light.

Drops of dew or rain, suspended to grass or bushes, may be frequently found to appear to the eye of a bright-red colour: by slightly shifting the position of the eye, the colour of the drop may be made to appear successively yellow, green, blue, and violet, and also colourless. This proves that the rays of light, falling in a certain direction upon the drop of water, are refracted thereby and decomposed into the coloured rays which become visible to the eye when it is situated in the direction of the emerging rays. We may, therefore, imagine the seven prismatic colours to reach our eyes simultaneously from seven different drops, provided the proper relative position between the latter and the former exists. This is frequently the case when the sun shines upon a quantity of drops falling from waterfalls, fountains, paddle-wheels, &c.

The rainbow is always observed to be situated in the west in the morning and in the east in the afternoon, so that in looking at it we must always stand with our backs to the sun, and have the cloud of rain before us. It is, however, necessary, for the production of a rainbow, that the height of the sun above the horizon should not exceed 42 degrees. Hence we generally observe this phenomenon in the morning or towards evening; and it is only in the winter, when the sun stands very low, that the rainbow is sometimes seen at hours approaching noon. The form of the latter is in reality that of an enormous circle, of which the half that is situated below the horizon is invisible to us. Circular rainbows are visible, however, under certain circumstances, particularly from the masts of vessels. As rays of light reach the eye from all parts of a rainbow, the former may be considered as the point of a cone, the base of which is the rainbow itself, and whose axis is represented by a straight line, passing from the centre of the bow through that of the eye, and, if prolonged, would touch the centre of the sun.

We usually observe a second rainbow close to the first, the colours of which are, however, much paler. This phenomenon is the result of a second refraction of the once-refracted rays by other drops of water, whereby the light becomes much fainter. It must also be observed that in the second rainbow, the order of colours is reversed, the red forming the outer largest circle, and violet the inner circle.

III. PHENOMENA OF CURRENTS.

Electricity—Magnetism.

173. If it were in our power to collect in this work all the observations made, and facts discovered, in the departments of electricity and magnetism, we should be filled with surprise and wonder at the industry and penetration displayed by natural philosophers. The description of all that has been done in this branch of Physics, since the middle of last century, would furnish volumes sufficient to fill a whole library.

But, notwithstanding the multiplicity of electrical and magnetical phenomena, it is a matter of great difficulty to trace their ultimate cause; it is, indeed, scarcely possible for us to form even a general conception thereof from individual effects, as we are able to do with heat, sound, and light.

The ether by which all matter is penetrated appears capable of being set into peculiar motion, which we term the *motion of currents*, possessing a characteristic tendency to return upon itself, in a manner analogous to circular motion. These currents may be considered as moving either in aggregations or in surfaces, giving rise to various phenomena, which become perceptible to us as electricity and magnetism. Some particular phenomena are the results of the mutual approach of two currents of this description from various directions. Thus, parallel currents attract each other, while those meeting from opposite directions repel each other.

The relations of bodies themselves to this kind of motion of ether may vary just as much as they do with the undulatory motion. Manifold effects are thus produced, of which we shall here mention only the most important. The terms employed in the description thereof do not, however, bear any reference to the above mode of viewing them, it not being sufficiently well grounded to be applied in the consideration of all electric and magnetic phenomena.

I. Electricity.

174. Electrical phenomena are produced, 1, by *friction* between different bodies; 2, by placing in *contact* bodies differing from each other, either in their structure, temperature, or chemical character; 3, by the transition of bodies from one condition to another; 4, by the chemical metamorphosis of bodies; 5, by various animals, either voluntarily or involuntarily.

The most important electrical phenomena arise from the first, second, and fourth causes.

175. (1.) *Frictional Electricity.*—A piece of sealing-wax, resin, or sulphur, when rubbed with wool, acquires the property of attracting light bodies, such as scraps of paper, hairs, &c., from a little distance. This is the most ancient electrical phenomenon, it having been known to the Greeks, who perceived it on rubbing amber, which they called *electron*, and from which the name electricity has, therefore, been derived. A glass tube, when rubbed forcibly with a silk handkerchief, acquires the same property. These substances are said to become *electrical* by friction, and the cause of their attractive power is the *electricity* imparted to them.

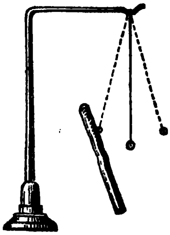
A great number of bodies do not possess the above property; they have, therefore, been termed *non-electric*, in opposition to *electric*, bodies. The former class of bodies may be represented by the metals, and the latter by the above-named substances. Accurate observation has, however, shown that there exists, strictly speaking, no perfectly non-electric substance, all bodies being liable to conversion into an electric state, although this property is possessed by some only to a very slight extent.

If glass or resin be forcibly rubbed in the dark, their surfaces will present a luminous appearance: on approaching the knuckle of a finger or any metallic object to them, when in this state, a brilliant *spark* will pass over to the former, accompanied by a crackling noise, and produce a slight pricking sensation at the point where it enters the finger. This phenomenon is called the *electric spark.*

Electricity exists always only on the *surface* of the electrified body, and is only abstracted from those points of glass or resin that are actually touched. If the rubbed glass or resin be approached by a metallic object, the electricity passes over to the latter, which is then possessed of all the electrical properties; it attracts light bodies and emits sparks. It is, however, remarkable that metals lose their electricity immediately and entirely, when they are touched only at one single point. Such bodies as abstract the electricity from electrified resin or glass, thereby becoming electric themselves, are called *conductors*, and other bodies that do not possess these properties are termed *non-conductors*.

Metals are the best conductors of electricity. Liquids, aqueous vapour, the bodies of men and animals, and fresh plants, are likewise very good conductors. Glass, resin, wool, silk, and *dry* air do not conduct electricity at all, or at least only to a very slight extent. If an object of glass be brought near to electrified resin, glass, or metal, it does not remove a trace of electricity. Hence the latter may be retained in any substance by surrounding it with good non-conductors. Thus, for instance, any metallic body, placed upon a disc of resin or plate of glass in *dry* air, and then electrified, will only part with its electricity on the approach of a conductor. When bodies are surrounded on all sides by non-conductors, they are said to be *insulated;* and the latter are, therefore, also called *insulators.*

If a small ball of cork be suspended to a silken thread (fig. 117), and a piece of rubbed sealing-wax be brought towards it, the ball will be attracted until it touches the wax; the moment, however, that this is the case the cork will be forcibly repelled. It has now taken up a portion of electricity from the wax. On again approaching freshly-rubbed sealing-wax to the ball, it will no longer be attracted; on the contrary, it will fly from the wax in an opposite direction: hence it appears that the two bodies charged with electricity derived from the sealing-wax mutually repel each other. If a glass tube be now rubbed with a piece of silk, and held to the cork, it will be observed that the latter will move towards the glass even from a considerable distance, being *attracted* by the electricity of the glass.



117.

If a ball of this description is charged with electricity from resin, and another with electricity from glass, and these be then approached until they

attract or touch each other, they will be found, after having been in contact, neither of them to possess any electrical properties whatever.

The following facts are deduced from the above simple experiments :—

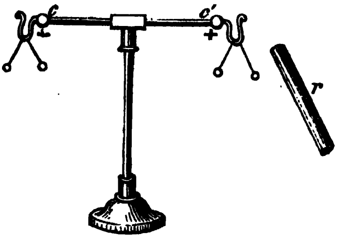
(1.) There are two kinds of electricity; first, that obtained by the friction of glass, which is termed *positive* or vitreous electricity, as also + electricity; secondly, that procured by the friction of resin, to which the name *negative* or resinous electricity has been given, and which is also designated as — electricity.

(2.) Bodies, charged with the *same kind* of electricity, *repel* each other, while those containing opposite electricities *attract* each other.

(3.) The opposite electricities always endeavour to unite. When once this is effected, *neutral* electricity ensues, *i. e.*, the two electricities mutually neutralize each other's properties, and electricity is no longer perceptible.

(4.) All bodies contain both electricities in the *combined* state: these may be separated from each other by various means, for instance, by friction. If, then, the rubbed body becomes positively electrified, the substance with which friction is applied becomes negatively electric.

176. *Electricity by Induction.*—The horizontal metal rod *c c′* (fig. 118) is insulated by being fixed upon a glass stand. A couple of cork balls are attached to each end by means of slender metallic wires. A rod of resin *r*, rendered negatively electrical by friction, is then brought near to one pair of the balls. It may be easily conceived that the negative electricity of the resin will attract the positive electricity of the metal and repel its negative electricity; the combined electricities in the latter are thus *separated*, the + electricity being situated at *c′*, and the — electricity at *c*. This is rendered perceptible by the behaviour of the balls. The two balls situated at *c′*, both containing + electricity, repel each other; as is likewise the case with the other two balls at *c*, which have become negatively electrified. On removing the rod of resin *r*, the separating cause is done away with, and the separated electricities in the metal will immediately reunite, which is proved by the balls falling together again.



118.

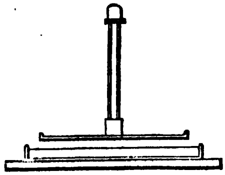
If the metal is touched with the finger at *c*, while the stick of resin *r* is still held near *c′*, the — electricity contained in the former extremity will be conducted off by the finger, while the + electricity collected at the other end will remain combined with the — electricity of the resin. On removing the finger first, and afterwards the resin, the whole rod will be charged with + electricity, as will be indicated by the mutual repulsion of the balls.

If we had employed rubbed glass instead of resin exactly the same phenomena would have taken place, except that in the above description all the electricity marked + and — should be changed, the + made — and the — made +.

This induction of electricity, therefore, affords us a means of charging any isolated body with + or — electricity at pleasure.

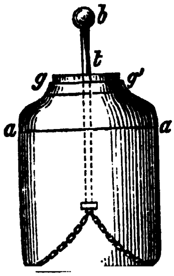
177. The *electrophorus* (fig. 119) is a very simple instrument, capable of affording an abundant supply of electricity by means of induction. A mixture

of two parts of shellac and one of turpentine is poured into a plate of metal, of about one foot in diameter and one finger-breadth in height, so that the mass yields, on cooling, a cake possessing as even a surface as possible. This is made electric by rubbing it with a cat's skin; a metal cover, furnished in the centre with a glass handle is then placed upon it. We will now proceed to examine the action of the electrophorus. It is assumed that the electricity of the cake has been separated by friction, so that − electricity is collected on its upper surface, while the + electricity is collected on the lower one. In placing the metal plate upon the cake an induction of electricity likewise takes place, since its + electricity is neutralized by the − electricity of the cake. On now touching the cover whilst in this position with the finger, its free − electricity is conducted away by the body. If the finger be removed, and the cover then lifted by its insulated handle, it will be found charged with free + electricity, which may be then employed for any experiments, in which glass or resin were previously made use of. If this apparatus be properly constructed, a very bright spark may be extracted from the charged cover on approaching the knuckle of a finger.


119.

When its electricity has been thus abstracted, it may be again charged as above described. It is remarkable that a spark may even be obtained from the plate, on lifting it up after the lapse of weeks or even months.

178. The *Leyden jar* (fig. 120) is a common glass jar, coated internally and externally with tinfoil to the height *a a*. The opening is closed by means of a bung or a piece of wood *g g'*, through which passes a rod *t*, furnished with a brass ball at the upper end, and terminating at the lower extremity in a chain, which should touch the bottom of the jar. On bringing the interior metallic coating by means of the ball in contact with any source of electricity (for example, the cover of the electrophorus) it will receive a charge of + electricity. The latter exerts through the glass a dispersing action upon the electricity contained on the exterior coating, by *combining* with the − electricity, and *repelling* the + electricity, which is conducted by the object on which the jar stands towards the earth, over the surface of which it distributes itself, and thus disappears.

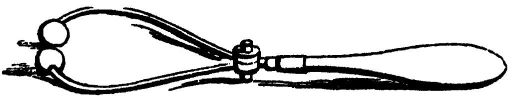


120.

The inner and outer coating of the jar are, therefore, charged with opposite electricities, which are prevented from combining by the glass situated between them. These will unite, however, at the moment that the two coatings are connected by a conducting body. If this connection be effected by touching the ball with one hand and the exterior coating with the other, the electricities will pass through the body, and a peculiar concussion, which is termed the *electric shock*, will be felt, particularly in the joints. Its intensity depends upon the charge of electricity in the jar: forty to fifty sparks, allowed to pass from the cover of the electrophorus into the jar, yield a sufficient charge to produce a very sensible shock. If several persons form a chain by joining hands, and the first one touches the knob, while the person at the

other extremity touches the exterior of the charged Leyden jar, a shock of equal force will be *simultaneously* felt by every person, however large the number of persons who form the circle.

The electricity may be also discharged from the jar without the production of a shock, by employing a *discharging rod* (fig. 121), constructed of brass, and provided with a glass handle. By laying hold of the latter, and touching the ball of the jar with one ball of the discharger, and the exterior coating with the other ball, the electricities will be united with the production of a very brilliant spark.



121.

179. A combination of several jars is called an *electric battery*: this is capable of producing tremendous shocks, according to the intensity of its charge. The sparks may be made to pass over at the distance of several inches, and are accompanied by a sharp report. Animals may be killed by such discharges. If the charge be allowed to pass through a long wire, interrupted at any point, a spark will pass over the space, provided it be not too great. The same phenomenon is observed if a wire be arranged with several small spaces, and very pretty and striking phenomena of light may be thus produced.

180. *Electrifying machines* (fig. 122) are employed for the production of powerful electric phenomena. The one in most general use consists of a glass plate, or disc, $\frac{1}{4}$ to $\frac{1}{2}$ inch in thickness, and 2 to 4 feet in diameter. It is moveable round its axis, and, when turned round, rubs against four cushions, which are covered with an amalgam of tin and mercury. The + electricity, thus liberated, is collected by the *conductor*, which consists of a hollow polished cylinder of brass plate, which is insulated by means of a stout rod of glass.

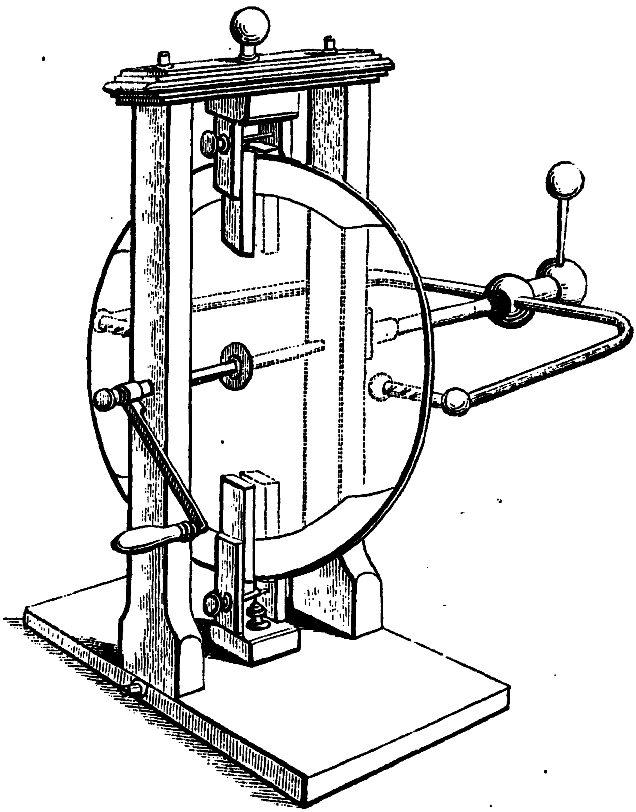
Such machines are employed specially for charging batteries, and also for performing a large number of experiments, which are partly of scientific interest, and partly of a popular and entertaining character.

181. As a general rule, it is highly essential that the atmosphere should be warm and dry, when electrical experiments are made, as the conducting property of moist air prevents the collection of a sufficient amount of electricity for the production of striking effects. In the winter, the experiments succeed best when performed near a fire; and it is advisable to place the apparatus in front of the fire for some time before it is employed.

182. The most striking and stupendous electrical phenomena are produced by Nature herself. Thus, the dazzling forks of lightning that break forth, flash after flash, from the clouds, followed by tremendous peals of thunder re-echoing through the skies, are nothing more than immense electric sparks, often miles in length. These discharges pass from one cloud to another, or to the earth, and are accompanied by a report corresponding to the crackling noise which each small spark makes as it passes from the electrophorus.

Although we are unable to form any accurate conception of the manner in which *free* electricity is collected in the different clouds, its existence therein was clearly proved by Franklin, in the year 1752, by means of a kite raised in the air, during a storm; the string, to which it was attached, being possessed of sufficient conducting power to exhibit electrical phenomena. These would

naturally be rendered more evident, by enclosing a wire in the string. It has since been proved that the atmosphere is frequently in an electrical state without



122.

any thunderstorms being observed; and from this we may with certainty assume, that electrical currents are universally distributed, and produce many effects that still appear to us enigmatical.

A cloud, for instance, charged with free electricity, on approaching the surface of the earth, acts by induction on the electricity of the latter; and the negative electricity will pass from the earth to the cloud until the two electricities have neutralized each other. In this manner most electrical clouds pass over the earth, without being accompanied by any striking phenomena.

If the electric cloud is very close to the earth, and there are lofty objects on the surface of the latter, such as trees, steeples, mountain summits, &c., from which a strong discharge of electricity takes place, the combination of the two electricities at those points is accompanied by a powerful flash; and hence we say that objects are *struck* by lightning.

183. Thunderstorms are rendered far less dangerous by the use of *lightning-*

conductors, which continually conduct the opposite electricity from the earth to the electric cloud, thereby neutralizing or diminishing the electricity of the cloud to a considerable extent. Should, however, a flash be emitted from the cloud even under these circumstances, it will pass over in preference to the elevated iron rod or wire of which the conductor is made; and as the latter is always constructed outside a building, and passes into the ground, the electric current will follow this good conductor, without touching the building. A good lightning-conductor may be considered as capable of protecting a space around it of about 40 feet in diameter.

As sound travels so much more slowly than light, the thunder is always heard after the lightning has been seen. It is only when a storm is just over our heads, and particularly when any object close to us is struck by lightning, that the thunder is heard simultaneously. The greater the interval between lightning and thunder, the greater is the distance of the storm. When the latter is very far off, no thunder is heard; we only see the lightning, which we then term *sheet lightning*.

The effects of lightning are always exceedingly powerful, and sometimes terrific. It annihilates all objects that lie in its path; fuses metals, ignites combustible substances, and destroys men and animals. But in the bodies of persons destroyed by lightning no external injury is in general perceptible. The electric discharge is always accompanied by a peculiar suffocating, sulphurous smell, which is sometimes noticed in a slight degree to emanate from powerful electrifying machines.

As electricity collects most readily in pointed objects, it is always advisable to avoid trees, steeples, high chimneys, &c., during storms. Single trees or clusters of trees on open fields are particularly dangerous: and unfortunate beings are constantly falling a sacrifice to lightning on such spots, to which they have fled for shelter from the storm and rain.

2. Electricity by Contact.

184. It has already been mentioned that substances, differing from each other either chemically or in their temperature or structure, produce electricity when brought into contact. This property is exhibited especially by metals. We shall choose copper and zinc from among these for our consideration, partly because they are powerful exciters of electricity, and partly because they are the two metals most generally employed for this purpose.

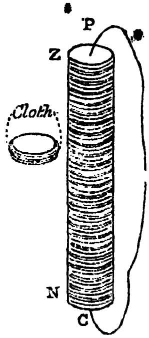
185. *Elementary experiment.*—If two extremely smooth and well-polished discs, one of copper and the other of zinc, each provided with an insulated handle, be placed upon each other, so that the polished surfaces are in contact, and again separated, the zinc will be charged with + electricity, and the copper with − electricity. The charges are, however, very slight, and can only be indicated by the most delicate electrometers, of peculiar construction. The plates themselves undergo at least no perceptible change.

The following is an experiment of a similar nature: two sheets of gold-paper are pasted together back to back, and in a similar manner two of silver-paper. They are then cut into discs of about the size of half a crown, which are piled upon each other in such a manner that gold and silver paper follow alternately: the column thus obtained is slightly compressed and introduced into a glass-tube, the ends of which are then closed with corks, through which are passed

pieces of wires. Piles of from 500 to 2,000 pairs may be thus constructed, the wires of which will be found, on examination, to be charged with opposite electricities. This apparatus is called the *dry pile*, or Zamboni's pile, and, under favourable circumstances, retains its power for years.

These two experiments afford almost the only instances in which electricity is produced by simple contact. In most other cases, chemical decomposition acts simultaneously with contact in the production of electricity.

186. Fig. 123 represents the *voltaic* or *galvanic pile*, called after Galvani, its discoverer, and Volta, the founder of the phenomena produced by contact. It is sometimes placed in a stand, the upper and lower parts of which are made of wood, and connected with each other by three glass rods. A disc of copper is placed at the bottom of the pile, and next to it one of zinc; these two discs being generally soldered together, by which the construction of the pile is much simplified. Upon the zinc disc is placed one of pasteboard, woollen cloth, or felt, previously soaked in water, and then pressed. More discs, of the different substances, are then placed upon these exactly in the same order; and thus a pile of from 20 to 40 pairs may be constructed, terminating at the top in a plate of zinc.



123.

The *zinc end*, P, of the pile is called the *positive pole*, and the *copper end*, C, the *negative pole*, as the respective opposite electricities, produced by the contact of the pairs of plates, are found collected at the extremities. On soldering wires to the terminating plates P C, as in fig. 123, they will form the two poles of the pile.

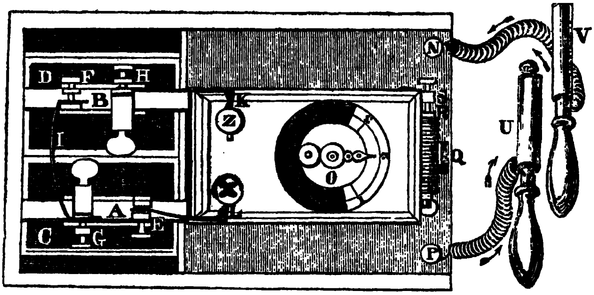
When these two wires are in contact, the circuit is said to be *closed*. No sign of electrical excitement is then visible; the action, nevertheless, continues in the interior of the pile. The opposite electricities collected at the poles, in particular, neutralize each other perfectly on meeting; every trace of electricity must therefore vanish, as when a Leyden jar is discharged, if a fresh quantity were not continually produced by every pair of plates: when the circuit is closed, two electrical currents are continually passing through the pile in opposite directions, and partially combine at every point of the *closing wire*. If, therefore, the latter be disconnected at any point, as seen in fig. 123, a continuous spark will pass from one wire to the other. The same takes place if the wires are severed at several points. It is of course requisite that the space between the wires should be of inconsiderable size.

187. The actions of the current, circulating in the pile, merit our special attention. Their results may be classed under three heads; 1. Phenomena of heat and light; 2. The excitation of nerves and muscles; 3. Chemical decompositions.

If a piece of fine wire of any metal be fixed from one conducting wire to the other, so that the electric current must necessarily pass through the wire, it will become hot, red-hot, and even heated to whiteness. Iron-wire burns under these circumstances, while wires of platinum, the most difficultly-fusible metal, will melt into small globules. The intensity of the phenomena depends upon the power of the pile. In some instances a platinum wire, 20 inches in length, has been kept at a red-heat by the electrical current. On fixing a point of carbon to

each wire, and approaching them until. they nearly touch, the passage of the electricity from one pole to another is accompanied by the production of a dazzling white light, rivalling the light of the sun.

188. Assuming the circuit of the pile to be closed, on taking a wire in each hand and breaking contact, a peculiar concussion will be felt in the joints of the arm and hand, accompanied by a slight contortion of the muscles, increasing to a very violent shock, which is repeated every time fresh contact is made. The concussion of the nerves of the body is, therefore, produced by the entrance and exit of the currents of electricity; for they evidently must pass through the body the moment it forms the connecting link between the two poles. By a particular arrangement, the circuit may be closed or interrupted at pleasure, and in such a manner that the current may be made to pass alternately through the wires and the body; the latter being thus exposed to a series of shocks which are considered particularly adapted for the cure of diseases arising from the injury or derangement of the nervous system, as, for instance, in cases of asphyxia, deafness, &c., the results, however, of this curative method, have not in general answered the expectations which were at first entertained. Numberless arrangements have been at various times proposed for the construction of medico - galvanic machines; but the one combining the most advantages is shown in figs. 124 and 125, which is composed of two batteries A B, with their respective cells C D. Each battery consists of a central thin plate of platinised silver, separated from the outer, or zinc plates, by means of a frame of wood. The binding screws, E F, after passing through the frames, are soldered to the silver plates, and the zinc plates are retained in their respective positions by means of the binding screws G H. The copper band I is used to connect the zinc plate of one battery with the silver plate of the other, and the wires K L are to afford a path by which the electricity may enter and leave the other parts of the apparatus.



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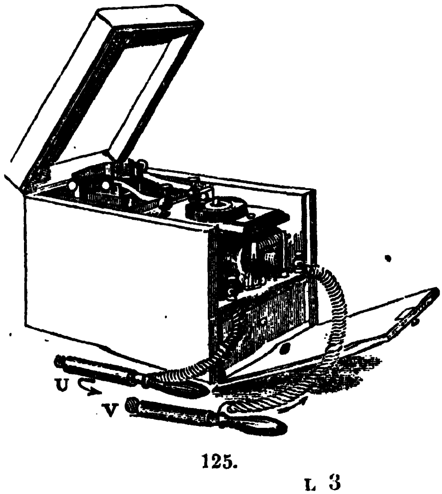


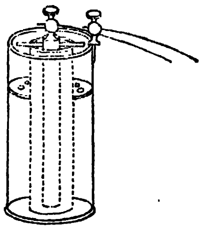
125.

To the binding screws, marked X and Z, are attached wires, leading into the interior of the coil machine. The indicator, O, is for the purpose of regulating the *quantity* of the current. The bundle of iron-wires, Q, serves to increase the *intensity* of the current. The contact-breaker, R S, is for the rapid making and breaking the battery contact, and the binding screws, P N, are for attaching the conducting wires of the directors U V, by means of which the current is transmitted to the patient.

189. The chemical action of the electrical current can only become intelligible to us after having studied chemical phenomena in general. At present it will suffice to say that the current exerts a tendency to decompose all chemical compounds, through which it is passed, into their elements. *Electro-metallurgy* is an application of this property of the electrical current.

190. We have made ourselves acquainted with the voltaic pile in its most simple form. It has at various times undergone a great number of alterations with regard to its elements as well as to its construction. The action of the pile is greatly increased by moistening the cloth, placed between the plates, in a solution of salt, or in dilute nitric acid, instead of in water, or by placing the pairs of plates in receivers containing such fluids, and connecting them properly by wires. In this case the electricity is increased to an extraordinary degree with the commencement of chemical decomposition. The power of a pile increases in general in proportion to the size and number of its elements. Several piles may be combined, and thus have their power united, as is the case with a battery of Leyden jars.

Daniell's *constant* battery, fig. 126, consists of a cylinder of copper, contain-



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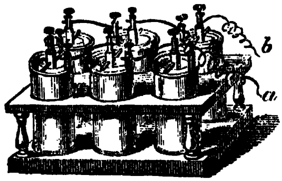
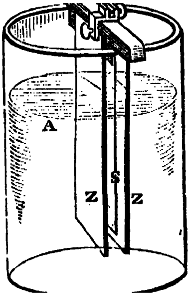


127.

ing a porous cell, in which is placed a solid rod of amalgamated zinc. The copper cylinder is furnished with a perforated shelf upon which crystals of sulphate of copper are placed, in order to keep the battery in constant action. This battery is excited by the solution of sulphate of copper in the outer cell, and dilute sulphuric acid, containing one part of acid to ten of water, in the inner cell. Fig. 127 represents six of Daniell's batteries in a mahogany tray, with connectors suitably arranged for obtaining either *quantity* or *intensity*.

Smee's battery, fig. 128, consists of a plate of platinised silver, S, having a bar of wood fixed at the top, to prevent contact with the zinc, and is furnished with two binding screws. A stout plate of amalgamated zinc, Z, is placed on each side of the wood, and both are retained in their position by the binding screws. This combination is immersed in a jar, A, containing dilute sulphuric acid, when, if a metallic communication is made between the poles or screws,

an active galvanic current is obtained. Fig. 129 represents a compound Smee's battery.



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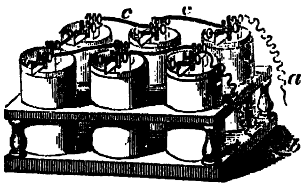
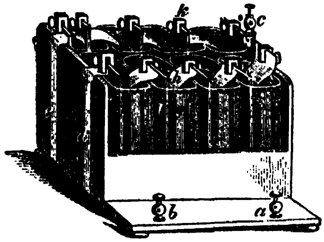


129.

The most powerful galvanic arrangement is shown by fig. 130, and is the invention of Professor Grove. It consists of slips of platinum *h*, placed in porous cells *g*, each cell being surrounded by a thick zinc cylinder *i*, contained in a glass or porcelain vessel. The platinum in each cell is attached to the zinc by the binding screws *k*; but at the extremities or poles, the platinum forming the one pole terminating in the screw *a*, is united by the band *e*, and the zinc forming the other pole, and terminating in the screw *b*, is connected by the band *d*. This battery is excited by filling the outer cell with dilute sulphuric acid, the inner porous cell with strong nitric acid.



130.

191. The powerful action of electricity by contact on the nervous system gave rise to its discovery in the year 1789. Galvani, on suspending some frogs' legs, from which he had removed the skin for anatomical purposes, to an *iron* railing, by means of *copper* hooks, observed that they underwent remarkable contortions. The phenomenon when more carefully studied, particularly by Volta, led to an endless number of discoveries with regard to electricity, and their source is evidently not exhausted yet.

Entire series of phenomena, of too complicated a nature to be explained in a brief outline like the present, are based upon the above observations; we shall therefore confine ourselves, in the following pages, to an examination of the reciprocal action between electricity and magnetism.

2. Magnetism.

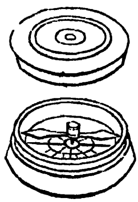
192. An iron-ore, pretty generally distributed in Nature, possesses the peculiar property of attracting small particles of iron, such as filings, and retaining them on its surface. This observation had already been made by the ancients, and the name of the phenomenon is derived from the village of *Magnesia*, where it is said to have been first noticed. The above mineral exists in

Sweden to such extent that it is worked for iron. It is called the *loadstone* or *magnetic iron.* This mineral attracts nickel as well as iron; but as the former can only be obtained, with the greatest difficulty, in the pure metallic state, we shall confine ourselves here to the consideration of the behaviour of iron with the magnet.

193. The magnetic property of loadstone may be easily imparted to *steel,* by rubbing the latter in a certain manner with a piece of the mineral. It is then called an *artificial magnet;* and, as it may be made in any form, it is employed for all magnetic observations. A thin and long piece of magnetized steel is termed a *magnetic needle;* and we will first proceed to make ourselves acquainted with the behaviour of this instrument.

If a magnetic needle be strewed over with iron-filings, a great number will adhere to both ends, while the centre will not attract a single particle. The terminating points of the needle, which are possessed of the highest attractive power, are termed its *poles,* while the place where no attraction exists, is called the *equator* of the magnet. The same may be found in all natural and artificial magnets, whatever may be their form. In magnets of regular form, the poles are generally situated at the two opposite ends, and the equator exactly in the centre.

194. If a magnetic needle be arranged so as to revolve easily on its vertical axis, it will always, when set in motion, oscillate from side to side, until it remains stationary in a certain position, to which it invariably returns, in whatever other direction it may be placed. One of the poles always points towards the north, and is called the *north pole* of the magnet, while the other necessarily points to the south, and is termed the *south pole.* This property of the magnet has led to its application as a *compass,* by which simple instrument the direction of any place may be determined when all other means of indication are wanting, as, for instance, on the open sea, in large forests, and in mines.



131.

195. If the south pole of a magnetic needle, supported as at fig. 131, be brought near to the south pole of another magnet, the extremity or point of the moveable needle will be repulsed. If, on the other hand, its south pole be brought near to the north pole of another magnet, it will be attracted by the latter until they come in contact, and will then cling to each other. Thence we see that *similar* magnetic poles repel, while *opposite* poles attract each other, as is the case in electricity.

196. Although iron and steel are in most respects so similar, they differ very much in their relations to magnetism. Both contain the two kinds of magnetism in combination. As long as this is the case, they are not observed to possess magnetic properties. In iron, the separation of the two kinds of magnetism may be easily, but only transitorily effected. The magnet, therefore, attracts it powerfully, converting it, however, only into a *temporary* magnet. The two kinds of magnetism are more difficultly separated in steel, hence the latter is but slightly attracted by the most powerful magnets. When once effected, however, the separation is *permanent,* and the steel becomes a perfect magnet.

Iron may be made magnetic by *induction,* in the same manner as electricity

was shown to be produced by induction. If, for instance, a piece of iron be attached to the north pole of a magnet, its magnetism will be decomposed in such a manner that the south pole of the iron is at the point of contact, and its north pole at the opposite extremity. On holding a small piece of iron to this end, it will be attracted, and likewise acquire polaric properties. Thus a small chain of little rods of iron may be formed, which will, however, fall to pieces as soon as the first piece is no longer under the influence of the magnet.

Steel becomes magnetic by being *rubbed* with a natural or artificial magnet. The north pole of a magnet is placed on the centre of a bar of steel and repeatedly drawn over it towards one extremity; the other half is subjected to a similar treatment with the south pole of the magnet; the bar is thus rendered magnetic, and only loses this property when strongly heated.

As we do not view magnetism as a substance, but as a peculiar current proceeding in a certain direction, it is obvious that an infinite number of magnets may be made by means of one artificial magnet, without the latter losing any of its magnetic properties whatever.

If we assume the action of the magnet to be, like that of the galvanic pile, the result of an excitation of every one of its particles, the sum of which appears to be collected at the two poles, it will not be a matter of surprise to find, on cutting a magnetic wire in half, that each piece will represent a perfect magnet, with two opposite poles and an equator. The case is the same as if we took from the pile several or only one pair of plates, each of which forms a small battery, possessing all the main properties of the larger one.

197. A steel knitting-needle, of uniform thickness, when suspended at its centre by a thread, will be in equilibrium, and occupy a *horizontal* position. If it be converted into a magnet, as described above, and again suspended, it will no longer appear to be in equilibrium: one end will exhibit a very perceptible downward inclination, just as though a weight were attached to it. The thread must be approached to the extremity of the needle that is inclined downwards, in order to re-establish the equilibrium.

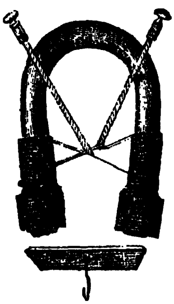
This experiment, together with the circumstance above mentioned, that the needle always points in one direction towards the north and south, lead us to the conclusion that some cause must exist for these phenomena. The earth may, in fact, be considered as a large magnet. Its magnetic poles are, however, not in exactly the same situation as the geographical poles; hence its magnetic equator does not coincide with the central line of the earth. The magnetism of the earth imparts to the magnetic needle not only its direction, but also the attraction that alters its equilibrium. As the magnetic north pole of the earth attracts the south pole of the needle, the extremity of the latter that points towards the *north* should properly be called its *south pole*.

In pursuing the northerly direction indicated by the magnetic needle, we should of course not ultimately arrive at the north pole of the earth, as its situation is not identical with that of the magnetic north pole. By extending in our imagination the direction indicated by the needle, we should obtain a circle round the whole earth, which is called the *magnetic meridian*. The latter intersects the meridian passing through the poles of the earth, at a certain angle, which indicates the amount of *declination* of the direction of the needle to the west of the true north pole.

The attractive power exercised by the magnetic poles of the earth must be

very unequal at different parts. If the compass be situated at the magnetic equator, its north and south poles will be attracted with equal force by the magnetic poles of the earth, and the needle will, therefore, occupy a perfectly *horizontal* position. On approaching the magnetic north or south pole, the compass will assume a certain *inclination*, increasing proportionably as the distance from the pole diminishes. The magnetic north pole has, in fact, been so nearly approached as to give to the needle a position almost vertical to the surface of the earth.

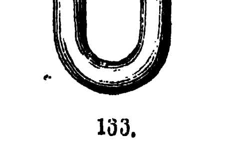
198. To the influence of the earth's magnetism may, therefore, be ascribed the circumstance that objects of iron and steel become endowed with magnetic properties to a slight extent, when strongly rubbed, beaten, or stamped, particularly if they are at the same time held in the direction corresponding to the declination and inclination of the needle. Thus, scarcely any implement will be found in the workshop of a smith or locksmith, to which small iron filings or scales will not adhere.



132.

199. The reciprocal action between electricity and magnetism is exceedingly remarkable. If a piece of iron, in the form of a horse-shoe, fig. 132, be wound round with copper-wire, and an electrical current then passed through the latter, the iron will exhibit the most powerful *magnetic* properties, which it loses, however, the moment the current is interrupted. If steel needles be employed in this experiment, they will become permanently magnetic. The conducting wires employed in these experiments are wound round closely with *silk*, in order that they may be insulated in coming in contact with each other, or with other metals, thus permitting the current to pass in their interior in one direction only.

On covering the ends of a non-magnetic piece of iron (fig. 133) with coils of wire, and imparting to the magnet *a b*, which is placed below, a rapid motion around its vertical axis, in such a manner as to cause the poles to approach each end of the iron alternately, an *electrical* current will be established in the wire, by means of which all the electric phenomena already mentioned may be produced.



133.

If an electrical current be passed through a spiral coil of wire, suspended in such a manner as to be moveable round its vertical axis, the wire will assume the position of the magnetic needle, and exhibit all its characteristic properties.

By this we prove the existence of an intimate reciprocal relation between the two kinds of currents, and this is termed *electro-magnetism*, a force to which has been attributed the common cause of these phenomena.

The fact of a piece of iron being endowed with a high magnetic power, so long as an electrical current is allowed to pass through a wire coiled round it, as shown by fig. 132, has led to experiments having for their object the application of electro-magnetism as a *motive power*; but hitherto no practical results have been obtained.

On the other hand, the application of electricity by contact to *electric telegraphs* has become of the highest importance. The following observations will furnish an idea of the principle of this invention:—If the two ends of the wire, wound round the horse-shoe-formed iron, are greatly extended so as to reach to a spot, at a distance of some miles, where a galvanic pile is situated, the piece of iron may be made alternately magnetic and non-magnetic, by closing the circuit of the battery or breaking contact. By this means, the horse-shoe may be made to attract, at intervals, a piece of iron placed close at hand: the motion thus imparted to the latter may easily be communicated, by a proper mechanical contrivance, to an index moving over a disc, upon which are marked the letters of the alphabet. A certain position is given to the index, so that, for instance, it points to the letter A on the first closing of the circuit, moving to B on the breaking of contact, thence to C by the second closing, and so on: thus, by making and breaking contact the appropriate number of times, the index may be made to point to any letter, and words or sentences are thus telegraphed from one place to another.

Electric telegraphs are constructed along railways: they combine the advantages of increased certainty and rapidity, over the old telegraphs, with that of cheapness and of being perfectly unimpeded in their operations by night or fog.

Thus as heat and light are most wonderfully associated together, so that one seldom appears unaccompanied by the other, and as every increased degree of heat leads to the production of light, so electricity and magnetism may likewise be more frequently dependent upon each other, than experiments and researches have hitherto shown.

The Northern Lights.

200. One of the most brilliant nocturnal phenomena, the *Northern Lights* (Auroræ boreales), appears to stand in connection with the magnetism of the earth, as a peculiar oscillation is imparted to delicate magnetic needles, on the appearance of a very powerful northern light, and as the latter is seen in a direction corresponding with that of the magnetic North Pole. This phenomenon of light has also been observed at the South Pole; but it most generally appears in the direction of the North Pole, which is situated nearer to us and is better known.

In its greatest brilliancy the Aurora borealis presents itself to us as an immense belt, consisting of fiery rays, and extending in a semicircle over the horizon, its extremities appearing to touch the earth. It exhibits the greatest variations in the brilliant changes of its colours, and the continued increase and disappearance of its rays. In the long dreary nights of the polar regions it diffuses over the spacious vault of heaven a thousand different lights of the most resplendent beauty. In our own part of the globe its yellowish-red appearance has not unfrequently excited the terror and alarm of the ignorant and superstitious, and even the more enlightened members of society have imagined the phenomena to be portentous of great events, and the harbingers of war, pestilence, and famine, whilst timid imaginations have sometimes shaped them into aerial conflicts.

> "Fierce fiery warriors fight upon the clouds
> In ranks and squadrons, and right form of war." *Shakspeare.*

ASTRONOMY.

"Hail, mighty Sirius, monarch of the Suns!
May we in this poor planet speak with thee?
Say, art thou nearer to His throne, whose nod
Doth govern all things?—Hast thou heard
One whisper through the open gate of Heaven,
When the pale stars shall fall, and yon blue vault
Be as a shrivelled scroll?" *Sigourney.*

1. ASTRONOMY is the science which treats of the heavenly bodies and of their motions. In reference to its object it forms a branch of Physics (comp. p. 53); but the importance and the extent of astronomical phenomena demand for this science an independent consideration. The phenomena of motion exclusively arrest our attention. The laws on which these motions depend are precisely the same as those which are partly explained in Physics, in the doctrines of Equilibrium and Motion; hence Astronomy has been, not unaptly, called by many the *Mechanics of the Heavens* (Celestial Mechanics).

2. The scene on which the phenomena of Astronomy are represented is called the firmament, or the heavens; and the objects that appear in this space or firmament are called the heavenly bodies, or more commonly stars. In the same manner as we have in § 2 of Physics defined space as something infinite, so we may consider the heavenly bodies as innumerable. This incomprehensible only partially unveiled, these immeasurable distances and immense masses of matter together with rapidity of motion equally inconceivable confer upon the phenomena of Astronomy, and consequently on the science itself, a great elevation and solemnity which do not belong to the other branches of Natural Science.

"The survey of unlimited distances and of immeasurable altitudes, the view of the great ocean spread out at the foot of man, and the greater ocean, the canopy of the heavens, spread out over his head, liberates the spirit from the confined limits of the actual, and from the oppressive shackles of physical life."

Although in these words of Schiller we find the elevating character of astronomical phenomena efficiently represented, still we do not agree with what is maintained by many, viz., that Astronomy is the first and the noblest of all the natural sciences. To the natural philosopher to whom the whole extent of nature belongs, all the individual branches of science constitute the links of an endless chain, from which not a single link can be detached without destroying the harmony of the whole. Erroneous views regarding the growth of the most insignificant plant are, to the truth-seeking mind, as unworthy as the absurdities of the antiquated ideas of the motions of the heavenly bodies.

3. The science of Astronomy is greatly dependent on Mathematics. The relations of space, number, and time, are the important problems to be solved. How large and how far, or how long and how often? These are the primary problems which this science proposes to solve.

Only the science of Mathematics, and especially the higher branches of Geometry and Trigonometry are capable of answering these questions; and it is a fact that the constant, progressive, and increasing demands of Astronomy have been the external propulsive cause to which mathematical science has been mainly indebted for its present high development.

Although it is impossible to follow exactly the course by which astronomers have been able to establish the most important truths of astronomical science, without a considerable knowledge of Mathematics; still the discoveries made by the learned in the laborious way of calculation, and the laws that have been deduced therefrom, may be represented in simple terms, so as to be intelligible even to those whose knowledge of Mathematics is not very profound.

Astronomy especially requires a frequent application of comparisons, in order to make her phenomena more easily comprehensible. It is manifestly difficult to form a conception of the magnitude of the earth, but it is still more difficult to imagine the exceeding vastness of the sun's dimensions, at least a million of times larger than our globe. On the other hand, we can more easily estimate these relative magnitudes, if we represent the earth by a grain of millet, and the sun by a skittle-ball. But how can we form an idea of endless space, with the innumerable heavenly bodies moving therein? This also may be compared to the space of a room, in which countless myriads of atoms whirl around each other as seen in one single sun-beam, which finds its way into the room.

4. The history of Astronomy is as ancient as that of the human race. For thousands of years the same star-bespangled heavens, which now surround us, like an enormous canopy, have awakened the attention of men and excited their admiration. We may here observe that the uncivilized tribes of the desert, and the nomadic inhabitants of the wide-spread steppes, watch the phenomena of the heavenly bodies with more attention than the inhabitants of our cities. For to those the stars serve as time-piece, sign-post, compass, barometer and calendar, hence they are compelled to direct their attention to the motions of the heavenly bodies; whilst the inhabitants of more civilized countries are not under the same necessity.

We are therefore indebted for a series of highly-important observations to

those of the ancients who, little advanced in science, but in the capacity of hunters and shepherds, were obliged to contemplate the starry heavens in order to determine the place and time.

5. It cannot be disputed that a preference is to be given to Astronomy over all other branches of natural science, because it can be studied to a certain extent without the aid of many artificial means. As soon as the glorious orb of day has set the twinkling stars shine forth in the darkening firmament, the larger ones appearing first, and after a time the smaller succeed, until at last myriads of distant worlds appear as a beautiful canopy before the astonished gaze of man. The nocturnal starry heavens afford to every one an accessible field of observation, on which by attentive consideration many important phenomena may be beheld without the aid of any kind of instruments whatever.

While the prosecution of natural philosophy requires a number of artificial and expensive instruments, and Chemistry, a large supply of materials and preparations, Astronomy merely requires her votary to elevate his eye to the firmament above him when he finds himself at once in the midst of celestial phenomena.

If, however, one series of astronomical truths is so accessible there is a still more considerable number invisible to the unassisted eye. An accurate investigation of astronomical phenomena can therefore only be made with the aid of instruments, and the purchase and erection of these are attended with so considerable an outlay as to render personal observation accessible to a few individuals only. It is this fact which accounts for a certain degree of incompleteness of the astronomical knowledge of the ancients, and it was only from the time when art lent new powers to the eye, by the invention of the telescope, that the field of observation was widened, and by the continued improvements of the instruments the results of observation were rapidly accumulated.

6. The evident influence of the sun upon the surface of the earth as the animating source of light and heat, the remarkable changes of the moon in form and time of rising must, in earlier times, have given to these two luminaries a high degree of importance in the estimation of the ancients, of which the divine honours they received, are, in some measure, a convincing proof to this day. It was also natural to ascribe even to the smaller celestial bodies a relation to the earth and its inhabitants, although this is not so conspicuous as in the case of the former bodies.

We can therefore easily conceive that, at a time when illusory conceptions, in reference to the stars and their phenomena, were prevalent, another influence was generally attributed to them, namely, that they were intimately connected with the destinies of the human race. For every great event, for every remarkable personage, for everything which the benighted and fettered mind of the vulgar could not rationally account, a solution and reason were sought in the stars.

Thus, it was this strange mixture of arbitrary assumptions, illusions, and errors, regarding the nature of the stars, that gave birth to Astrology, which for hundreds of years mystified and perplexed instead of enlightening and enlarging the human mind. It was this, in connexion with superstition and knavery, that brought contempt and persecution upon science, and continually retarded its progress, until the human mind, based on unprejudiced observations, tore

asunder its shackles, and learned that the earth is truly a point of space, but not the central point: that the stars are independent worlds, not mere marks and signs for illustrating the destinies of the passing generations of this little earth.

7. In our endeavour to give in the following pages an exposition of the most important astronomical phenomena, we shall not accomplish our task without previously giving an explanation of a number of aids which this science requires in order to render its study more clear. Geometry is the branch of science from which most of these aids are derived, and if we assume them partly to be generally known a brief outline of this science is requisite to insure an adequate comprehension of the following. After we have in this manner become, in some measure, acquainted with the astronomical method of observations, language, and expressions, we shall proceed to the consideration of those phenomena, which by day as well as by night are unceasingly displayed in the heavens. Hereby we shall acquire a true insight into the arrangement of the heavenly bodies, and be able to divest ourselves of the erroneous notions of former times.

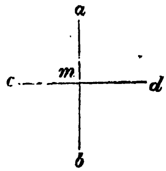
The subject is divisible into the following sections:—

I. Aids to Astronomical Observation.
II. General Astronomical Phenomena.
III. Special Astronomical Phenomena.

I. AIDS TO ASTRONOMICAL OBSERVATION.

Angle.

8. On a plane, a sheet of paper for example, we describe two lines *a b* and *c d* (fig. 1), which intersect each other in the point *m*; thus the plane is divided into four parts.

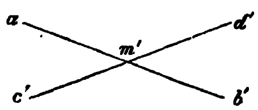


1.

Each of these parts is called an *angle*, and the two lines, by which each angle is contained or included, are its *sides*, and the point where they cut each other or intersect, is called the *vertex* of the angle. Thus *a m* and *c m* are the two *sides* of the angle *a m c*.

If we cut out with a pair of scissors the four angles situated about the point *m*, and on applying them to each other, find that they all are exactly of the same size, that is, that the four sections exactly cover each other, we call these angles *right* angles; and in this case the lines *a b* and *c d* cut each other at right angles, or are perpendicular to each other.

Again, if we consider fig. 2, we see at a glance that the lines *a′ b′* and *c′ d′* do not intersect at right angles, but that the plane is divided into four very unequal angles. On cutting out and comparing one of these with an angle of fig. 1, it is evident that the angle *a′ m′ c′*, fig. 2, is smaller than the right angle *a m c*, fig. 1, and that the angle *a′ m′ d′* is considerably larger than a right angle.



2.

Angles which are smaller than a right angle are called *acute*, and such as are greater are called *obtuse* angles. Around the point *m′* there are the two acute angles *a′ m′ c′* and

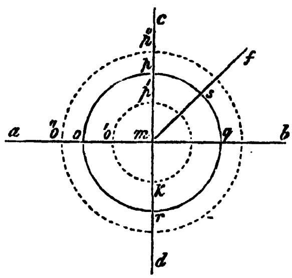
$d'm'b'$, as well as the two obtuse angles $a'm'd'$ and $c'm'b'$. Hence we deduce, that round a given point no more than four right angles can be constructed, and only three obtuse angles; and, on the contrary, that an infinite number of acute angles may be formed round the same point; and further, that of the four angles represented in fig. 2, the two opposite vertical angles are equal, and the two *adjacent angles*, $a'm'c'$ and $a'm'd'$, unequal to each other, are together equal to two right angles.

These relations are perfectly independent of the length of the sides which include the angle. For if we suppose that the lines ab and cd (fig. 1), or $a'b'$ and $c'd'$ (fig. 2), are extended indefinitely, still the angles m and m' formed at the point of intersection, remain unchanged.

9. The mutual inclination of the lines including the angle is always determined by the magnitude of the angle. Thus the situation of a point in relation to a plane is partly determined, if we know the angle, formed by a line drawn from that point to any point of the plane. This principle renders the angle so exceedingly important, that it is capable of being employed as the key to the most important truths; for a great part of the actual observations of astronomers are dependent on the study of angles.

The next object is to determine the magnitude of the angle.

To determine the size of an angle the circle is employed. Suppose we describe a circle ($opqro$) about the point of intersection m of the lines ab, cd, which cut each other at right angles, there is opposite to every one of the four right angles a curve-line or arc of a circle, which is exactly a fourth part of the circle; for example, over the angle amc is the quadrant or fourth part of the circumference op. That the magnitude of the circle is indifferent, is shown by the dotted lines; for $o''p''$ and $o'p'$ are quadrants as well as op.



3.

The acute angle cmf is hence equal to half a right angle, because the arc by which it is subtended is an octant, the eighth part of a circle, and the obtuse angle amf is equal to one and a half right angle, because its subtending arc is equal to three-eighths of the circle.

Thus we can very accurately determine the magnitude of an angle, when we state the portion of a circle which the arc of that angle forms.

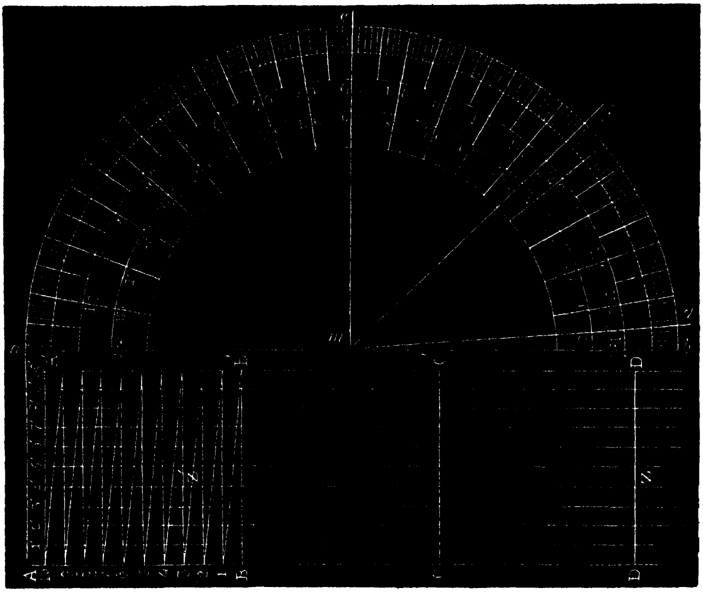
For this purpose the circle is divided into 360 equal parts, each of which is called a *degree*. And every degree is again divided into 60 equal parts, called *minutes*, and every one of these again into 60 *seconds*.

Hence, when we speak of an angle of 90 degrees, we necessarily mean a right angle, since 90 degrees are the fourth part of the 360 degrees of the whole circle. Every angle less than 90 degrees is an acute angle; and every angle of more degrees is an obtuse angle.

For accurately measuring angles, a simple instrument called a *protractor* is employed, and this is generally made of brass.

The protractor (fig. 4) is a section called a semi-circle, which is divided into 180 degrees. If by this instrument we wish to measure the angles amc, amf, cmf, and gmb, we place the protractor so that the centre of the semi-

circle and the vertical point of the angle may coincide, and then read the number of degrees. We thus find that *a m c* is equal to 90 degrees, and,



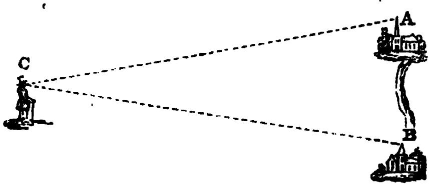
4.

therefore, a right angle; that *a m f* is equal to 135 degrees, and, therefore, an obtuse angle: also *f m b* is an acute angle of 45 degrees, or half a right angle; and, finally, *g m b* is a very acute angle of only 5 degrees.

In accurate mensuration, the minutes and even seconds of a degree are measured. The number indicating degrees is distinguished by a small cypher (°), the minutes by a dash (′), and the seconds by two dashes (″); thus, for example, an angle = 90° 35′ 16″ signifies an angle of ninety degrees, thirty-five minutes, and sixteen seconds.

10. Only a *drawn* angle can be measured by the protractor. When an angle in which only imaginary lines intersect each other is to be measured, another instrument is employed.

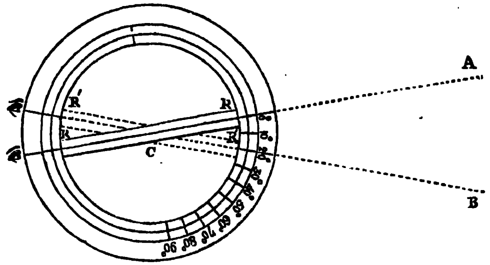
For example, if the angle formed by the lines extending from two distant steeples A and B, to the eye of the observer, where they meet in C (fig. 5), is to be determined, the simplest apparatus for this purpose is the *angle instrument* (fig. 6). This is constructed of a metallic ring, the rim of which is divided into degrees, and called the *limb*. In the centre, C, of this circle there is a pivot about which a rod or bar, R R, called the index-arm, revolves in



5.

a similar manner to the hand of a clock.. The instrument is placed horizontally upon a small table, so that its centre, C, is situated exactly in the place where the lines drawn from A and B are supposed to intersect.

The index is next directed to the part of the limb marked with 0°, and the instrument so adjusted that the point A may appear to the eye in the same straight line as the index-arm. This is subsequently moved round the pivot till the point B is in its direction, which is the case if it has the position R′ R′; in this manner the index-arm describes an arc which is measured on the graduated limb of the instrument, which in the present case is 20°; consequently the angle at C over which this arc is situated is 20°.



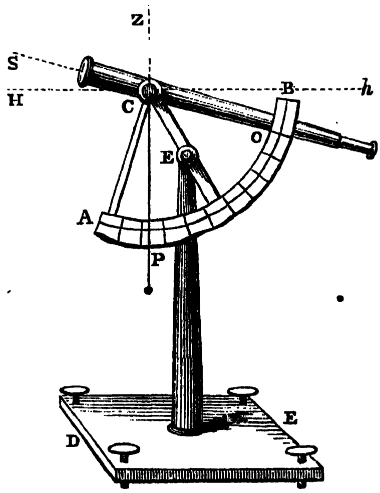
6.

This is the fundamental arrangement which we find with more or less variation in all astronomical instruments for measuring angles.

It is evident that, according as the angle to be measured is either vertical or horizontal to the surface of the earth, the circle of the instrument must be placed either parallel with or vertical to it. This latter position of the instrument must be adopted in measuring the angle formed by an imaginary line drawn from the top of a tower to a point on the surface of the earth with the surface.

In cases where angles are to be measured, the extent of which does not exceed that of a right angle, or an angle of 60°, it is more convenient to employ a quadrant or a sextant than an entire circle.

Fig. 7 represents a quadrant moveable round the point E. A B is the limb, and C the centre of the quadrant. The instrument is so disposed that a telescope which is attached to one of its sides may be directed to a point in the horizon H, in the line H h, and the other side, C A, may coincide with the line of the plummet P attached to C; after this adjustment the telescope is directed to the star S, when the plummet which retains its vertical position marks off on the limb of the quadrant the number of the degrees of the angle, which a line drawn from the star to the observer makes with the horizon.



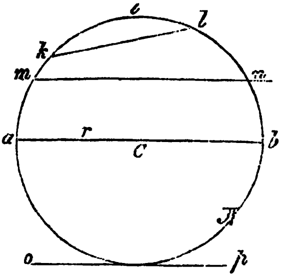
7.

The construction of angle instruments has now reached to such a high degree of perfection, that an angle of one second, and even of half a second can be measured. The

angle of one second is but $\frac{1}{324000}$ of a right angle. To realize the idea of an angle so excessively minute as one second, we may suppose a line drawn from the upper and under side of a human hair to a point three feet distant: these two lines would contain an angle of a second.

Circle.

11. Suppose we fix a nail in a table, and attach to it a thread, and to the other end of the latter a black-lead pencil. With this we describe a line round the nail; keeping the thread equally stretched during the operation. A *circle* is thus described, with this essential quality, that every point in this line so drawn is equally distant from the point on which the nail is fastened, and which is termed the *centre* of the circle. A straight line drawn from the centre of a circle to a point of its circumference, such as is in the above example described by the stretched thread, is called the *semi-diameter*, or *radius*, of the circle; and it is evident that all the half diameters or radii of a circle are equal. If the radius is extended till it meet the opposite part of the circumference, it will form the *diameter* of the circle, which is evidently the double of the radius. All diameters also of the same circle are therefore equal. (See fig. 8.)



8.

c = centre.
$a\,c$ = semi-diameter = r.
$a\,b$ = diameter = $2\,r$ = d.
$k\,i\,l$ = arc of the circumference.
$k\,l$ = chord.
$m\,n$ = secant.
$o\,p$ = tangent.
$d\,\pi$ = circumference, $\pi = 3 \cdot 14$.

Any portion of a circumference, $k\,i\,l$ for example, is called an *arc;* and the straight line $k\,l$, uniting its two ends, is called the *chord* of that arc. A line $m\,n$, cutting the circle in two points, is called the *secant;* and a line $o\,p$, outside a circle, touching the circle in one point only, is called the *tangent.* The circumference is denoted by $d\,\pi$ or $2\,r\,\pi$, the Greek letter π representing the number $3 \cdot 14$, the circumference being $3 \cdot 14$ times longer than the diameter. Suppose the length of the diameter to be 4 inches, that of the circumference will be $4 \times 3 \cdot 14 = 12 \cdot 56$ inches.

The superficial contents of the circle is equal to $r\,r\,\pi$, which shows that it is found by multiplying the semi-diameter by itself, and the product by the number $3 \cdot 14$.

Sphere.

12. Particular attention must be paid by the student to the sphere, which is a body with a convex surface, and every point of which is equally distant from a point within the sphere, called the *centre.* A straight line drawn from the centre to any point of the surface is a *semi-diameter*, and the extension of this line to the opposite surface of the sphere is called the *diameter.* As in the circle, so also in the sphere, all the semi-diameters and diameters are equal.

Let us suppose a sphere intersected by planes which pass through its centre, these planes will represent the *great circle* of the sphere, whose radius is equal to the radius of the sphere.

The *superficial contents* of a sphere, or its superficies, is found by multiplying the superficies of one of its great circles by four, and may be expressed by the formula $4\pi r r = \pi d d$. The surfaces of two spheres have the same relative proportion to each other as the squares of their diameters.

The *cubic contents* of a sphere are found by multiplying one-third part of the radius by the superficial contents, and may be represented by the formula $\frac{1}{3}(4\pi r r r) = \frac{1}{6}(\pi d d d)$. The relative contents of two spheres of unequal magnitudes are to each other as the cubes of their diameters, or as their diameters three times multiplied by themselves.

It appears desirable to give some examples illustrative of the foregoing statements in reference to the circle and the sphere, and we adopt for both a diameter of 12 inches:—

Diameter = 12 inches.

Semi-diameter = r = 6 inches.

Circumference = $12 \times \pi = 12 \times 3{\cdot}14 = 37{\cdot}6$ inches.

Area of the circle = $r \times r \times \pi = 6 \times 6 \times 3{\cdot}14 = 113$ square inches.

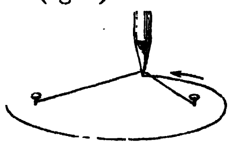
Superficies of the sphere = $4 \times (r \times r \times \pi) = 4 \times 113 = 452$ square inches.

Cubic contents of the sphere = $(\frac{1}{3} \times r) \times 4(r \times r \times \pi) = 2 \times 452 =$ 904 cubic inches.

The superficial contents of a sphere of 6 inches diameter and one of 12 inches diameter are, according to the above rule, as 6×6 to 12×12, or as 36 to 144, and their cubic contents as $6 \times 6 \times 6 = 216$, to $12 \times 12 \times 12 = 1728$.

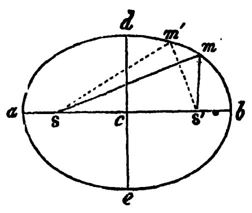
Ellipse.

13. The *ellipse* and its properties are much less generally known than the circle. This is also a figure contained by a curve line, which is produced in the manner following:—Suppose two pegs fixed on a plane (fig. 9). A thread, longer than the distance between the pegs, is fastened by one end to the first peg, and by the other to the second peg. If we now stretch the thread by means of a lead-pencil and draw a line around the two pegs as wide as the stretched thread will allow, we describe an oval figure which is called an *ellipse*.



9.

This figure has a long axis $a\,b$ (fig. 10); and perpendicular to this a short axis $d\,e$, passing through the centre c. The two points S S′ are called the *foci* of the ellipse; also, as is evident from the construction of the figure, any two lines drawn from the two foci, to any point of the circumference, for instance, S and S′ m or S m' and S′ m', &c., which represent the thread when the pencil is at m or m', are together equal to the larger axis of the ellipse. These lines, and we may imagine an infinite number of such, are called *radii vectores.* The distance of the foci S or S′ from the centre c, is called the *excentricity* of the ellipse. It is evident that the smaller the excentricity is, the nearer the figure approaches to that of the circle. The superficies of the ellipse is found by multiplying the two half axes, $a\,c$ and $d\,c$, by each other, and this product by the number $3{\cdot}14$.

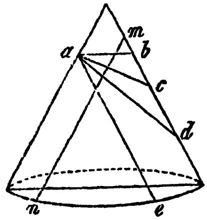


10.

The ellipse has special claims on our attention, inasmuch as it is the path described by most of the heavenly bodies, as, for example, that of the earth which is nothing but an ellipse.

PARABOLA.

14. Another curved line, having peculiar properties, is the *parabola.* This figure is most easily represented by the aid of a cone, by which also several other curved lines, commonly called conical sections, may be represented. Thus, if we make diagonal sections of a cone parallel to the base, as, for example $a\ b$, we obtain only circular planes; but on the other hand, oblique sections through both sides of the cone, as $a\ c$ and $a\ d$, form ellipses. If the cone is cut by a plane parallel to one of its sides, as in $a\ e$ and $m\ n$, the plane obtained is circumscribed by an entirely different curved line, namely, a *parabola*, the peculiarity of which consists in the fact of its ends never meeting, as in the circle and the ellipse, but continually becoming more distant from each other, even if continued *ad infinitum.*



11.

The orbits of some of the heavenly bodies are parabolas; as, for example, those of several of the comets, which, consequently can never appear again, unless in the lapse of time they alter their direction.

MENSURATION.

15. By Mensuration is understood the most accurate division of any line, surface, or space by a given measure. The result of mensuration informs us how many times this measure is contained in the object to be measured.

In the Physical portion of this work (§ 7) we have given a comparative view of the smaller measures of length, and have assumed the *meter* as unit. This measure is obtained when the fourth part of a great circle, the plane of which cuts the earth at the poles, is divided into ten millions of equal parts. This measure bears to the English imperial yard the relation of—

Meter.		Yard.
1·	=	1·093633
0·91438348	=	1·

Again, the circumference of the earth at the equator is divided into 360 degrees.

DISTANCE—DIAGONAL SCALE.

16. If we suppose one definite point in space determined, then every other point is *distant* from that assumed point; and the straight line which can be drawn, or which may be imagined to be drawn, from the one point to the other, is called the shortest distance, or simply their *distance.* As space is boundless, no measure and no number can limit distance.

We speak of *commensurable* and *incommensurable* distances. The first are such as we can either measure directly by the application of a measuring instrument, or by calculation; and different measures or scales are employed, according to the magnitude to be measured. Thus we express the distances of the

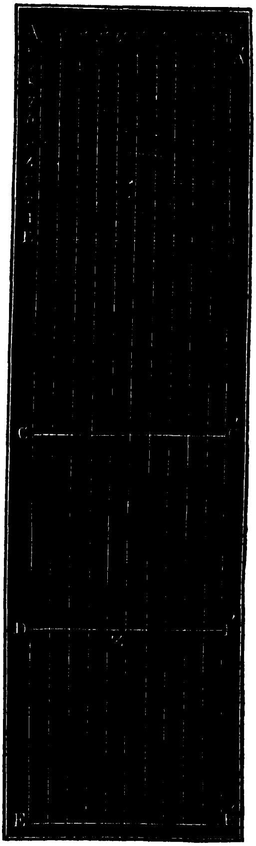
heavens by the distances of the stars, of the sun, and by semi-diameter of the earth. We measure the surface of the earth by degrees, miles, rods, &c., and objects of less extent by feet, inches, and lines.

Incommensurable distances are such as we can neither determine by our senses nor by our instruments. For example, we say that the distance between one atom of matter and another is incommensurably small, and the distances of most of the fixed stars and of the Milky Way incommensurably great.

All distances greater than the eye of sense can reach we bring within the range of our spiritual optics by the powers of imagination. But sometimes even these are insufficient, for the enormous distances of the heavenly bodies are beyond the sphere of imaginative power

In such cases the *diagonal scale* (fig. 12) is an essential means in aiding the imagination, since by the use of this instrument we can make diagrams which represent the same ratios upon a plane which can easily be seen

In this instrument, constructed on mathematical principles, the lines A B, B C, &c , represent given spaces, as miles, A B is divided by ten parallel lines into tenths of a mile, and from these points, 1, 2, 3, 4, &c., lines are drawn to the right hand, diagonally to A′, B′, intersect the parallels 1′, 2′, 3′, 4′, &c., in such a manner, that from every tenth of a mile, again the tenth part is marked off. The marked-off section amounts to $\frac{1}{10}$ upon the parallel 1′, $\frac{2}{10}$ upon 2′, to $\frac{3}{10}$ upon 3′, to $\frac{9}{10}$ upon 9′, so that by means of a compass, any magnitude required may be measured in miles, tenths, and hundredths of miles. For example, $2\frac{1}{4}$ miles, or 2·25, is laid down from the scale, thus—place the one point of the compasses at Z, and extend the other to the point of intersection of the diagonal 3, and the parallel 5′ at Z′, and the space between the points of the compasses corresponds exactly to two entire miles two tenths and five hundredth parts. A diagonal scale of this description is frequently appended to the bottom of the instrument called the protractor, as in fig. 5.

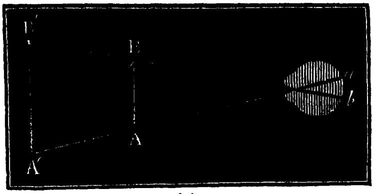


12.

Angle of Vision—Apparent and Actual Magnitude

17. In our Physical section we have shown that from every object that we see, rays of light penetrate the eye and form an image of the object upon the inner coating (*tunica reticulata*) of this organ, on the magnitude of this image, made perceptible to us through the optic nerve, the apparent magnitude of the object depends. Let us suppose, for example, lines drawn from the two extremities *a b* (fig. 13) of an image formed on the retina corresponding to

the object, these lines intersect each other, and form the visual or optic angle, whose magnitude is dependent on that of the image on the retina. It may, therefore, be said that the apparent magnitude of an object is expressed by the magnitude of the angle of vision under which it appears. It is a general rule, that the greater the visual angle the greater is the apparent magnitude of an object.



13.

The magnitude ot the angle of vision evidently depends on two things, the first is the actual size of the object, and the second is its distance from the eye. And in reference to the latter this law is prevalent, viz., that the angle of vision, under which an object is seen within certain limits, decreases with the increase of the distance of the object. The same object at double the distance will appear to have only half, and at three times the distance only a third of the magnitude which it has in the single distance.

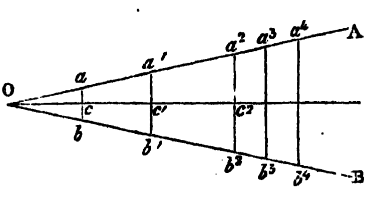
For the same reason, the trees of two parallel rows appear to approximate more and more according to their remoteness, because their relative distance appears to the eye under a smaller angle. Illusions of different kinds depend on this principle; and we have only by experience gradually acquired the habit of determining the distance of known objects by their apparent magnitude. In the twilight, or in a fog, which renders the outlines of objects indistinct, a distant church steeple or a tree may easily be mistaken for a man close to us, or *vice versâ*, because the angle of vision of the lofty but distant object may appear the same as that of an object which is of less height, but nearer to the observer.

Two consequences can be deduced from the foregoing principle, of the utmost importance in the science of astronomy, namely, first, when the apparent magnitude and the distance of an object are known, its actual magnitude can be determined; and, second, when the actual and apparent magnitudes of a body are determined, the distance of the body itself can be ascertained.

Determination of Distance.

18. Only short distances are in general measured by actual measurement with a rule or chain; consequently there is no necessity for explaining this process, inasmuch as these practices are seldom employed, even in measuring large distances on the earth, and never applied in determining the distances of the heavenly bodies.

Here we do not deal with distances *measured* but *reckoned*. For this purpose we require from geometry some principles regarding the similarity of triangles; and a few laws from trigonometry.



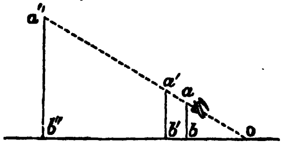
14.

In fig. 14 we perceive between the sides A *o* and B *o* of the angle *o*, the parallel lines *a b*, *a' b'*, &c. It is evident that these lines are the longer the farther they are distant from the angle *o*, and it can be proved that *a' b'* is as many

times longer than $a\,b$, as $o\,c'$ is longer than $o\,c$, and as many times as $o\,a'$ is longer than $o\,a$, and as many times as $o\,b'$ is longer than $o\,b$. The same remarks apply to all the other drawn or imaginary parallels between the sides $o\,A$ and $o\,B$ in relation to $a\,b$, or between any two of these parallels. Thus $a^4\,b^4$ is as many times longer than $a^3\,b^3$, as $o\,a^4$ is longer than $o\,a^3$, &c.

This simple principle is applicable to the mensuration of perpendicular distances or heights, as well as of horizontal distances. For example—

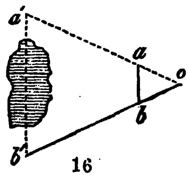
Let $a''\,b''$ (fig. 15) be a tower, the height of which is to be ascertained. We first measure accurately a ground or base line $b''\,o$, then set up a staff $a\,b$, over the top of which the eye can see the summit of the tower a''. Let a second staff $a'\,b'$ be so placed between the tower and the observer that its top a' may appear to the eye in a straight line with a''. By drawing a line connecting these four points, a'', a', a, o, we obtain a diagram corresponding exactly to fig. 14, and from the above principle, it follows that $a''\,b''$ is as many times longer than $a'\,b'$ as $b''\,o$ is longer than $b'\,o$. Suppose, for illustration, that $a'\,b'$ is 15 feet high, and $b'\,o$ 30 feet long, then must also $a''\,b''$ be half as long as the measured base line. But this line is 120 feet, therefore the height of the tower is 60 feet.



15.

By the length of the shadows thrown by two objects, we can ascertain the height of the objects by which they are cast; and this affords us a very simple method of determining the altitude of objects. For example, we measure a staff fixed in the ground $a'\,b'$ (fig. 15), and also its shadow; we then measure the shadow of a tower $b''\,o$. Hence, so many times as the staff is longer or shorter than its shadow, so many times is the height of the tower longer or shorter than the length of its shadow.

We apply the same principle with suitable modifications to the determination of the mutual distance of two points ($a'\,b'$, fig. 16), which we cannot measure directly, as, for instance, when a wood or lake intervenes. In this case it will be sufficient to ascertain the distance $o\,b'$ in order to determine that of $a'\,b'$ as well as $a'\,o$. Let two staffs be fixed in the ground at the point a and b, which are in the same straight lines with a' and b', and with the eye of the observer at o; draw $a\,b$ parallel with $a'\,b'$, find the measure of the triangle $a\,b\,o$, then as many times as $o\,b'$ is longer than $o\,b$, so many times is $a'\,b'$ longer than $a\,b$.



16

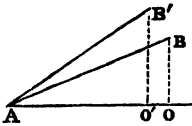
Trigonometrical Mensuration—(Measuring of Angles.)

19. We occasionally find on certain elevated positions, as, for example, on the tops of hills and mountains, erections of wood or stone, of greater or less altitude, and an inscription sometimes is added, importing that this is a *trigonometrical station*. It is generally known that such stations are employed to survey the surface of the country, and that the latter is by this means divided into a number of triangles, spread out like a net. These triangles being measured, their sum gives the contents of the surface surveyed.

It is difficult to convey to the uninitiated in mathematical science a clear

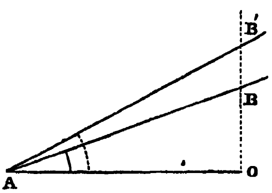
notion of the process whereby these surveys are made; we will, however, endeavour to render it comprehensible.

The angle A (fig. 17) is contained by the sides A B and A O. From the extremity B of the side A B, let a perpendicular B O fall upon the side A O. The line A B is supposed to be of an unchangeable length, and hence it is called the *constant*, and we assume that it is moveable round the point A. We raise the constant A B till it occupies, for example, the position A B′. Thus we see that both the angle at A, and also the perpendicular, let fall from the extremities of the constant, must increase. The angle B′ A O′ is evidently greater than B A O, and B′ O′ longer than B O; this increasing line is called the *sine* of the given angle A.



17.

Again, let us suppose in the same angle A (fig. 18), that the side A O is invariable, and on the end O erect a perpendicular O B, and extend it till it cuts the other side A B. As the angle at A is increased, so also is the perpendicular, which we call the *tangent* of the angle A.

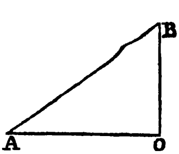


18.

We hence understand that the sine and the tangent are two lines, which bear a certain relation to a given angle, and increase with the enlargement of the angle. It is easy to perceive that the tangent of the angle A is susceptible of a much greater increment than the sine, and a law has been discovered, and trigonometrical tables have been constructed, in which the proportion of the sine and tangent to the constant of every angle is given. For example, if we look in the table for the sine of the angle of 30 , we find the number 0·5 is given: that is, the sine of this angle is only half as great as the constant.

From what has been above stated, the important practical application is clear, viz., that from the given magnitude of an angle and one of its sides, the sine or the tangent can be found, with the aid of the trigonometrical tables, as may be thus exemplified:—

Let it be required to determine the height of a tower O B (fig. 19). By previous admeasurement, the base A O is found to be 430 feet, and the angle A 35°. O B is the tangent of the angle A, which by the tables is equal to 0·7; that is, the tangent O B is 7-10ths of the constant A O, and 1-10th of 430 being equal to 43, O B is equal to 7 × 43 = 301 feet.

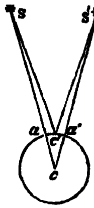


19.

Distance and Magnitude of the Heavenly Bodies.

20. The methods which have been described in § 18 are never applied to measure vertical or horizontal distances on the surface of the earth; trigonometrical calculations are always employed. These last are the only means possible for ascertaining the distances of the heavenly bodies. As in this case the semi-diameter of the earth is taken as the base line, the length of this must first be determined, which is done in the following manner:—Let us suppose

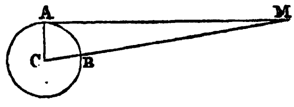
the earth to be represented by the circle fig. 20, and two observers by a and a', being distant from each other just the length of the arc $a\ a'$, which by accurate admeasurement is known to be 138·2 miles. Each of these observers simultaneously takes notice of a fixed star, perpendicularly over his head $s\ s'$, the two lines drawn from the star to the observers will, if extended, meet in the earth's centre and form the angle c. We cannot measure this angle, because the centre of the earth is inaccessible, the distance, however, of the fixed stars from the earth is so excessively great that it makes no perceptible difference whether the angle, formed by the lines uniting the two stars s and s' with the observer's eye, be measured from the centre or from a point c' on the surface of the earth. To employ an illustration



20.

—it is as of little influence as if a mite in the centre or on the surface of a millet-seed were to look at the summits of two distant mountains. Without sensible error, we therefore assume the angle c to be equal to the angle c', and measure the latter. If this is equal to 2°, we know that the arc $a\ a'$, equal to $138\frac{2}{10}$ miles, stands over an angle of two degrees, and consequently that $69\frac{1}{10}$ miles = 1°, which for the whole circumference of the earth, amounting, as is known, to 360°, is $360 \times 69\frac{1}{10} = 24{,}876$, or more correctly, 24,897 miles. But as (§ 11) the circumference of a circle is 3·14 times as great as its diameter, the diameter of the earth is consequently $\frac{24897}{3 \cdot 14} = 7929$.

21. If two persons, A and C (fig. 21), from different stations, observe the same point M, the visual lines naturally meet in the point M, and form an angle, which is called the angle of *parallax*. If the eye were at M, this angle would be the angle of vision, or the angle under which the base line A C of the two observers appears to the eye. The angle at M



21.

also expresses the apparent magnitude of A C when viewed from M, and this apparent magnitude is called the *parallax* of M.

Let M represent the moon, C the centre of the earth represented by the circle, then A C is the parallax of the moon; that is, the apparent magnitude the semi-diameter of the earth would have if seen from the moon. If the moon be observed at the same time from A, being then in the horizon, and from the point B, being then in the zenith, and the visual line of which when extended passes through the centre of the earth, we obtain, by uniting the points A C M by lines, the triangle A C M.

Therefore, as A M, the tangent of the circle (§ 11), stands at right angles to the radius A C, the angle at A is a right angle, and the magnitude of the angle at C is found by means of the arc A B, the distance of the two observers from each other. As soon, however, as we are acquainted with the magnitude of two angles of a triangle, we arrive at that of the third, because we know that all the angles of a triangle together equal two right angles (180°). The angle at M, generally called the moon's parallax, is thus found to be 56 minutes and 58 seconds. We know that in the right-angled triangle M A C the measure of the angle M = 56′ 58″, and also that A C, the semi-diameter of the earth = 3964 miles. This is sufficient, in order by trigonometry, to

obtain the length of the side M C; that is, to find the moon's distance from the earth. A C is the sine of the angle M, and by the table the sine of an angle of 56′ 58″ is equal to $\frac{1652}{100000}$; or, in other words, according to § 19, if we divide the constant M C, the distance of the moon, into 100,000 equal parts, the sine A C, the earth's semi-diameter = 1652 of these parts. And this last quantity being contained 60 times in 100,000, the distance of the moon from the earth is equal to 60 semi-diameters of the earth, or $60 \times 3964 = 237{,}840$ miles.

In a similar way the parallax of the sun has been found = 8″, 6, and the distance of the sun from the earth to be 95,000,000 miles.

22. Having ascertained the actual distance of the sun and moon, and their apparent magnitudes, their actual magnitudes may be thence readily calculated. Let us assume, for example, A C (fig. 21), to be the moon's semi-diameter, and A M the moon's distance from the earth, then A C will be the trigonometrical tangent of the angle M, if we make A M the constant. But now it has been found by observation that the apparent diameter of the moon, or the angle of vision under which it is seen by the observer at M = 31′ 16″. The apparent magnitude of the semi-diameter of the moon amounts therefore to 15′ 38″; but the trigonometrical tangent of an angle of 15′ 38″ stands to the constant as 454 : 100,000. As the constant A M is = 237,840 miles, we obtain for A C, = $\frac{454 \times 237840}{100000}$, 1080 miles, and for the actual diameter of the moon, which is equal to twice A C, 2160 miles. In the same manner we calculate from the apparent diameter of the sun, which is = 32′ 0″ 88-100th, and from his distance the actual diameter at 882,270 miles.

II. GENERAL ASTRONOMICAL PHENOMENA.

(A.) THE EARTH.

FIGURE.

23. We presuppose the reader to have a general notion of the spherical form of the earth and heavenly bodies, and of their motions in space; we, therefore, reserve the proofs for a subsequent portion of the work.

The following facts are confirmatory of the spherical form of the earth. We can only see a very small portion of its surface from any station whatever; if the earth were a plane, our extent of view would not be so limited as in fact it is. If we observe a ship receding from our sight on the apparently flat ocean, the first part which disappears is the hull, and lastly the masts and pennon. An exactly similar appearance is observed when a person walks up and over a hill, his feet disappear first and his hat last, and, *vice versâ*, in approaching our station his hat appears first. Voyages and travels by land and by water have shown indisputably that it may be travelled or sailed round by constantly proceeding from one point in the same direction, and that the traveller will at last arrive at the very place whence he set out on his journey. We farther conclude, from the circular appearance of the earth's shadow, as

seen in a lunar eclipse, that the body casting this shadow is spherical. Finally, by actual observation, we know that the other heavenly bodies are spherical.

Notwithstanding the sphericity of the earth, the surface appears to us as a plane, this appearance being a consequence of its great extent. Even from the tops of mountains of 10,000 feet in height, the eye can survey only the 1-4000th part of the earth's surface, and hence this little space appears as a plane.

Magnitude of the Earth.

24. It has been already shown in § 20, that it is possible to measure a body even of so great magnitude as the earth. A tabular view of the relative terrestrial magnitudes is given below.

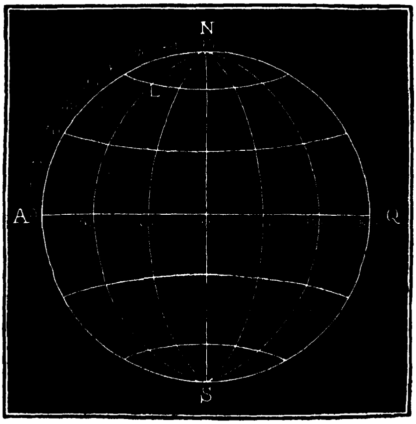
Diameter of the earth	=	7,929	miles.
Circumference	=	24,897	miles.
Superficial contents	=	197,408,788	square miles.
Solid contents	=	260,875,713,342	cubic miles.

It is evident from these numbers, that the elevations on the surface of the earth, viz., the mountains, have no influence at all upon its general figure. Indeed, if we suppose that the earth is represented by a globe of 16 inches diameter, the highest mountains would resemble small grains of sand of $\frac{1}{100}$ inch in height attached to the surface of this globe.

Division of the Earth.

25. A skittle-ball rolling upon a bowling-green has another motion in addition to that of the course it follows. We perceive that the grains of sand adhering to its surface describe, according to their position, smaller or larger circles around two opposite points of the ball, and we term the imaginary line passing through the centre of the ball and these points, the axis of rotation, or, briefly, the axis of the ball.

It has been proved that the earth (fig. 22) likewise turns round an axis, N S, the two extremities of which are named the *Poles*. The one, N, is called the *North Pole*, and the other S, the *South Pole*, and the great circle AQ, drawn round the globe equally distant from the two poles, is called the *Equator*, as it divides the earth into two equal parts, viz., into the northern and southern hemispheres.



22.

The equator is divided into 360 equal parts or *degrees*, every one of which, as has been already shown in § 20, is 69 $\frac{1}{10}$ miles long. We may imagine a circle drawn through each of these divisions round the globe, and passing through the poles, so that the globe appears encircled with 180 rings, of which we here can only represent a few—as 30, 60, 90, &c. These vertical

circles passing through the equator and the two poles are called *meridians*, and of course have all the same magnitude. At the equator a meridional degree is 69 $\frac{1}{10}$ miles long; but, as is evident, this continually diminishes towards the poles, where they all meet. In reckoning meridians we commence at a certain point called the first meridian, as, for instance, at A (fig. 22), which was formerly on the island of Ferro, on the west coast of Africa, then supposed to be the westernmost point of land. In England the meridional degrees are calculated from Greenwich.

The distance of any meridian from the first meridian is termed the *Longitude*, and it is employed in describing the situation of a place on the earth's surface. Suppose L (fig. 22) a city, its longitude will be 30°, since it lies on a meridian which is 30° from the first. So, for example, the longitude of Oporto is 8° 37′ west, Paris 2° 22′ east, Vienna 16° 16′ east, Bagdad 44° 45′ east, Surat 73° 7′ east, Java 110° east, Mount Hecla 350° east, reckoned from the meridian of Greenwich, and so on until we return to the first meridian, or the point where we began to reckon. At the 180th degree we have proceeded half round the globe, and reached the farthest distance from the first meridian, and are now on the opposite side of the earth, and proceeding farther we ultimately arrive at the point whence we started.

26. It will readily be perceived that a knowledge of the longitude alone is not sufficient to determine the situation of a place on the earth's surface. When we say, for example, that the longitude of a place is 30°, it may lie on any point whatever of the whole hemisphere, N L S (fig. 22). This point must therefore be determined more accurately, and hence the first meridian is divided into 90 equal parts north and south of the equator towards the poles. These are called *degrees of latitude*, and the lines drawn through these round the globe, parallel to the equator, are called circles or *parallels of latitude*, and diminish as they approach the poles.

Hence, by the *latitude* of a place we mean its distance from the equator towards the poles, and we speak of north and south latitude according as the place is situated in the northern or southern hemisphere.

So, for example, the point L (fig. 22), which has 30° longitude and 60° north latitude, is in Sweden.

For greater precision, these degrees of latitude and longitude are farther divided into minutes and seconds. These divisions of the earth's surface are made very intelligible by means of a ball, whereon the principal lines above mentioned and the outlines of the continents, as well as some of the most important places are marked. An arrangement of this description is called a *terrestrial globe*.

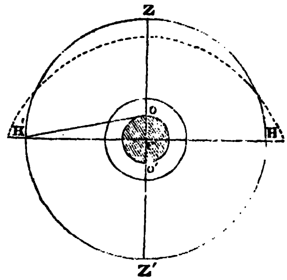
By way of example we give the *longitudes* and *latitudes* of several places in the following table:—

PLACE.	Longitude from London.	Longitude from Ferro.	North Latitude.
London - - - - - -	0° 0′	18° 6′	51° 31′
Athens - - - - - -	23 52 East.	41 32	38 5
Augsburg - - - - -	10 17 ,,	28 33	48 21
Berlin - - - - - -	13 26 ,,	31 3	52 31
Cologne - - - - - -	6 29 ,,	24 35	50 15

PLACE.	Longitude from London.	Longitude from Ferro.	North Latitude.
Constantinople - - -	28° 53′ East.	46° 36′	41° 1′
Darmstadt - - - -	8 9 ,,	26 15	49 56
Frankfort-on-the-Maine -	7 55 ,,	26 1	50 7
Göttingen - - - -	9 30 ,,	27 36	51 32
Hamburg - - - -	9 32 ,,	27 38	53 33
Königsburg - - - -	20 4 ,,	38 10	54 43
Leipzig - - - - -	11 55 ,,	30 1	51 20
Mannheim - - - -	2 1 ,,	20 7	49 29
Munich - - - - -	11 8 ,,	29 14	48 8
Paris - - - - - -	2 25 ,,	20 0	48 50
Petersburg - - - -	30 19 ,,	47 59	59 56
Prague - - - - -	14 15 ,,	32 5	59 5
Rome - - - - - -	12 32 ,,	40 38	41 54
Riga - - - - - - -	23 41 ,,	41 47	56 57
Stralsund - - - -	23 6 ,,	41 12	54 19
Vienna - - - - -	16 28 ,,	34 2	48 12
Worms - - - - -	7 55 ,,	26 1	49 38

(B.) DIVISION OF THE HEAVENS.

27. The earth is the station from which the eye of man beholds the Universe. We might presume, without any precise knowledge of astronomy, that many things would appear under a different aspect if the eye beheld them from the moon or the sun, or from one of the most distant stars. Therefore, we must divide the firmament surrounding us, and define the particular points, lines, and spaces in the same, without which it would not be possible to describe the phenomena occurring in it with any degree of precision.



23.

The spherical form of the earth does not admit of a top and a bottom, and hence every observer assumes that his station is the highest. Let us suppose, for example, that we are stationed on the point *o* of the earth's surface (fig. 23); an inhabitant on the opposite point is under our feet; but an inhabitant of the earth at *o′* would have as good a reason for considering himself as over us.

From the station of the observer at *o* let a line be drawn perpendicularly; if this line be prolonged indefinitely through the centre *c* of the earth to the point Z, which is over the observer's head, and to the opposite point Z′, the former Z will represent the *zenith*, and the opposite point Z′ the *nadir* of the observer.

Let us suppose one of the heavenly bodies, for example the sun, in the station Z, we say that such body is in the zenith of the observer at *o*. But the heavenly bodies at the nadir Z′ cannot, of course, be seen at the same time by the observer.

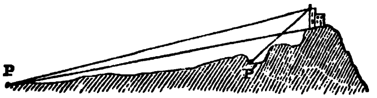
28. If we look from *o* on the starry vault of heaven, the stars glittering in it appear to the eye as if all were equally distant. We have an impression of

being surrounded by an enormous dome, on the inner ceiling of which the stars appear to be attached. The apparent firmament which surrounds the earth is represented by Z H′ Z′ H Z, and the distance from *o* to Z is to be assumed as infinitely greater. It is further to be noticed that, in consequence of an optical deception, the concave heavens do not appear hemispherical, but rather flattened, as the dotted line indicates.

Apparent and Real Horizon.

29. If the observer, instead of surveying the firmament above him, looks around over the surface of the earth, he appears to be bounded on all sides by a circle, of which he himself is in the centre. This appearance is represented more completely when the point of observation is on the smooth, open sea, or on an elevated point as the summit of a mountain. The circle which limits the view on all sides is called the *visible*, or *apparent horizon*, and meets, and apparently supports, the vaulted arch of the heavens, which seems to rest thereon. It has already been stated that the eye cannot see more than 1-400th part of the earth's surface from the top of a mountain 10,000 feet high, and from a height of 25,000 feet, the greatest elevation yet reached by man, the semi-diameter of the circle of vision amounts to 198 miles.

From the summit of a mountain (fig. 24), at the base of a tower, we perceive the distant point P as distinctly as from the top of the tower. The altitude of the latter is too little to have any perceptible effect on the appearance of a far-distant object, or to extend the range of our vision. For observing proximate objects, the height of the tower has an influence, as is proved by the point P′, being visible from the top of the tower, but not from its base.



24.

The distance of the nearest of the heavenly bodies from the earth is so enormously great that it is immaterial from whatever part of the earth, whether from its surface or from its centre, they be observed. The semi-diameter of the earth *o c* (fig. 23) is, compared with those immense distances, an insignificant magnitude; and it is certain that an observer, whom we may suppose to be stationed at the centre of the earth *c*, can see no larger a portion of the heavens, than he who is situated on its surface at *o*. Indeed, a star at H′ is just as visible from *o* as from *c*, hence a plane H′ *c* H, which cuts the earth through the centre perpendicularly to another, cutting the earth through the zenith and nadir (Z Z′) of the observer at *o*, will be the *true horizon* of the observer at *o*. This plane, which divides the heavens into two equal portions, the one above and the other below the horizon, is the *horizon of Astronomy*. It is evident that objects below the horizon are invisible.

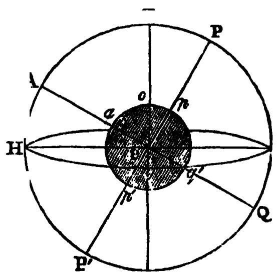
Apparent Motion of the Heavenly Bodies.

30. When we are moved or carried with a considerable velocity, as, for example, in a railway carriage, it appears to us that all the objects which we pass, contiguous to the line of motion, are moving rapidly in an opposite direction. That this motion is only apparent is so well known that it would scarcely deceive a child.

We daily experience, however, a similar illusion, in consequence of the rotatory motion of the earth around its axis. It appears to us that we are at rest in the centre of the vast concavity of the firmament, which, with its stars, seems to revolve round the earth. This was indeed the opinion prevalent for thousands of years, and there was no little difficulty in establishing the correct views.

We shall, however, in our consideration of celestial phenomena, treat the subject in the first instance as if the earth was really the fixed centre of the firmament. Therefore, whenever the rising or setting of the sun or stars forms the subject of description, such motions are to be understood as only apparent. In common life all the expressions regarding apparent motion have been retained, and the greater part of Astronomy consists, as it were, in the translation of apparent celestial phenomena into the actual.

31. The attentive observation of the starry heavens, even during a single night, will convince us that all the visible stars describe circles which are the smaller, the nearer the stars are to a certain point of the heavens P (fig. 25). In close proximity to this point there is a tolerably bright star called the *Pole Star*, which has scarcely any motion, but appears to the eye as always occupying the same position. Hence a line P P′ drawn from this star, through the centre of the earth c, represents the axis around which all the heavenly bodies perform their apparent motions. The part of the celestial axis P P′ passing through the earth, is the earth's axis; the north pole, of which p is on the same side as the pole star, and the south pole p' is on the opposite side.



We have, therefore, by the aid of the stars, determined the position of the earth's axis, and by this latter we can assign to the equator its proper place. For if $p\,p'$ be the earth's axis, $a\,q'$ is the greatest circle drawn round the earth, equally distant from both poles, and the plane of which cuts the earth's axis at right angles.

Furthermore, let us suppose the plane of the equator to be extended till it reach the celestial concave; we thus find the place of the celestial equator A Q, or *equinoctial*, as it is generally termed in opposition to the equator, which always means the terrestrial equator. The equinoctial divides the heavens into the northern and southern hemispheres. We cannot actually describe the equinoctial and make it visible, but we can imagine its line of direction by observing those stars through which it passes.

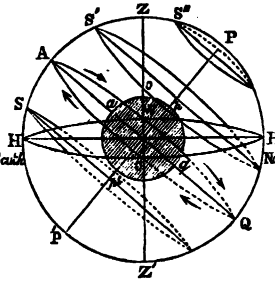
We are now in a condition to assign to an observer different stations in relation to the earth's axis on the earth's surface, which will essentially modify the aspects under which celestial phenomena are represented. One of these stations may be supposed to be at one of the two poles, for example, at p, or at any one point of the equator, as at a, or, finally, on any portion of the surface of the earth which lies between the pole and the equator, as, for example, o.

As the last is the station naturally occupied by most observers, and by all Europeans, we will first describe the phenomena as they appear to an observer

placed at the station *o* (fig. 25). This is 50° from the north pole, and corresponds to the latitude of Frankfort and Central Germany.

Diurnal Phenomena.

32. If, on the 21st March, a little before six o'clock in the morning, we look towards the brightest part of the horizon, we perceive at the point O (fig. 26) the *rising* of the sun. We call the exact point where this phenomenon occurs, the *East*, and that point W, of the horizon directly opposite, and distant 180° from the East, we call the *West*. If we turn our back to the East and look to the West, the point of the horizon on our left, distant 90° from the West, is the *South*, H, and the point opposite, on the right is the *North*, H′.



26.

These four points are called the *cardinal points*, and the straight lines which unite two opposite cardinal points intersect each other at right angles in the centre of the earth. The line H H′ which unites the north and the south is named the *meridian*.

33. The rotation of the earth round its axis is in the direction from West to East, contrary to the apparent motion of the sun and stars. Consequently we see the sun, after his rising at O, progressively advancing more and more in the direction of the arrow towards the meridian in an arc which cuts the horizon in the point of the angle O A W (fig. 26), which is called an *oblique* arc. In this manner the sun finally reaches the highest point A of the heavens, which is called the *point of culmination*, and the time at which this takes place is called *mid-day*. From this instant we perceive the sun progressing in the direction of the second arrow, descending towards the horizon, and disappearing or *setting* in the west point W. While the sun is above the horizon, his dazzling brightness illumines the surface of the earth and the atmosphere above the observer, in such a manner as to outshine all the other heavenly bodies, and to render them invisible. The period elapsing between the sun's rising and setting we call *day*, and the arc O A W, which the sun describes, the *diurnal arc*.

As soon as the sun has set the day is terminated; the twilight appears, and is succeeded by night, which veils the earth in darkness. The concave vault of heaven is then bespangled with the gradually emerging stars, sometimes accompanied by the moon, the light of which considerably diminishes the darkness of the night. The arc W Q O, which the sun describes under the horizon, is named his *nocturnal arc*. At Q he reaches his lowest point, which is called his *inferior culmination*.

The time which the sun requires in this manner to describe his apparent motion from O to A W Q, and back again to O, is termed a *mean solar day*, or, briefly, *day*, and is divided into 24 hours.

By inspecting fig. 26, we perceive that the sun's course through the diurnal and nocturnal arcs O A W Q O on the 21st of March, is the same line which we already (§ 31) have described as the equinoctial, or celestial equator: on this day the sun therefore passes through the equinoctial. We also know

that the diurnal arc O A W is equal to the nocturnal arc W Q O, and, consequently, that both day and night have an equal duration of 12 hours each. The period when this phenomenon occurs is called the *vernal equinox.*

The duration of the day and night, it is well known, varies considerably in the course of the year; therefore the sun during the whole year cannot remain on the equinoctial. Some weeks after the vernal equinox, the sun appears to the observer at *o* at mid-day some considerable distance higher above his horizon H H′, and nearer to the pole P, and he continually approximates to the pole till the 21st of June, when he reaches his greatest altitude at S′, which is then $23\frac{1}{2}°$ above the equinoctial. It is evident that on this day the diurnal arc described by the sun is longer than his nocturnal arc, and, consequently, the day is considerably longer than the night. Therefore, on the 21st of June we have the longest day, and the sun is said to be in the *summer solstice.*

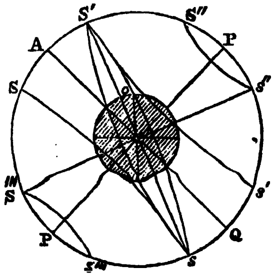
From this day, the arcs described by the sun again gradually approach the equinoctial A Q, which he enters on the 22nd of September, and we have again equal day and night, or the *autumnal equinox.* From this time, the southern distance of the sun from the equinoctial gradually increases, his diurnal arc, becomes smaller and smaller, and the days consequently shorter and shorter, till, on the 21st of December, he has arrived at the *winter solstice,* when we have the shortest day. From this point the sun again daily approaches the equinoctial, to which he returns on the 21st of March.

The time which elapses during these observations, and which is employed by the sun in ascending from the equinoctial to the highest point S′, and in descending to the lowest point S, and, finally, again entering the equinoctial, is named a *year*, and is exactly 365 days, 5 hours, 48 minutes, and 48 seconds.

We also see that the sun, to an observer at *o*, does not rise and set every day in the same point of the horizon, but that, while the days increase, the sun rises and sets at a point more northerly towards H′, and more towards the south H, when the days decrease. The point O where the sun rises at the equinox is also termed the *vernal point.*

The Ecliptic.

34. From what has been previously said, it is evident that the sun has a twofold apparent motion, viz., a circular motion obliquely ascending from the horizon, which is explained by the rotation of the earth, and by our position *o* to the earth's axis *p p′*, and also by a rising and setting motion between the solstitial points S and S′, which causes the inequality of the days and nights. Independently of the daily motion of the sun, we observe that at the summer solstice on the 21st of June, at mid-day, the sun is at S′, and one half year later, viz., on the 21st of December, at midnight, the sun is at *s*, from which he arrives again in the space of half a year at S′; so we are able to represent this annual motion of the sun, by a circle, the diameter of which is the line S′ *s*. This circle is called the *Ecliptic.*



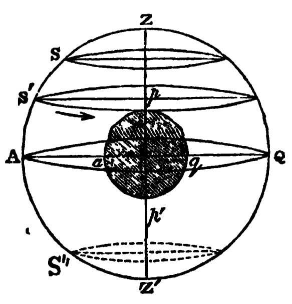
27.

The plane of the ecliptic S′ *s* cuts the plane of the equinoctial A Q at an angle of 23½°, and the axis of the ecliptic S‴ *s*″ makes the same angle with the axis of the heavens P P. The two parallel circles, S′ *s*′ and S *s*, include a zone, extending on both sides of the equinoctial, and beyond which the sun never passes. These circles are called the *Tropics*, from τρέπω, *I turn*, because the sun turns back at these points and again approaches the equinoctial. The parallel circles S″ *s*″, and S‴ *s*‴ described by the poles of the ecliptic S‴ *s*″ about the celestial poles P P, are called the two *arctic circles.*

Nocturnal Phenomena.

35. The stars, as well as the sun, in describing their courses in the heavens, reach an upper point of *culmination* (S A S′ S″, fig. 27), and a lower point, which is situated upon the opposite side of the celestial sphere. But we can actually perceive both these points of culmination only in such stars which, as S″, are closer to the pole, P. These stars never set to us; and in the vicinity of the north pole they may be seen by day, for example, when the sun is totally eclipsed. The more distant stars, S′ A S, complete their daily course partly under the horizon, consequently, they rise and set. Some, which are very remote from the north pole, barely rise above the horizon, and speedily disappear. Finally, those nearer the south pole, as S‴, describe their revolution round about the pole without being at any time visible to the observer at *o*. We never find the fixed stars, like the sun, change their position relatively to the equinoctial and the poles. A star on the equinoctial at A to-day, will describe, every following night of the entire year, its course on the equinoctial; and all the other stars are subject to this general law, for example, we find S S′ S″ the whole year through, and, at the same time, always in the same relative position.

36. Very different celestial phenomena from the above-described, are, however, observed when the place of observation is at the equator, or at one of the poles of the earth. If we suppose our station to be at the north pole, *p* (fig. 28), the pole star will necessarily be in the zenith Z, and the plane of the horizon will coincide with that of the equinoctial A Q. When the sun is above the horizon, he describes a circle round the horizon without setting. The stars S S′ likewise describe circles which are parallel to each other and to the horizon A Q, and hence to the observer at *p* they neither rise nor set.

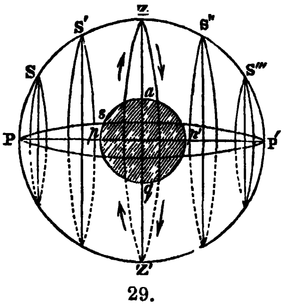


28.

As will be afterwards shown, the sun is for half the year constantly above the horizon of those who live in the vicinity of the north pole, and the day is consequently six months long. The night which follows is of equal duration, the sun being under the horizon, and then the sun is visible at the south pole during a period of six months.

37. If an observer is placed on the terrestrial equator at the point *a* (fig. 29), the earth's axis *p p*′ being extended, its extremities will lie in the horizon P P′ of the observer. Whilst the pole star at P′ in the horizon appears immove-

able, all the other stars, for example, S, S′, Z, S″, S‴, rise in a perpendicular direction over the horizon P P′, and describe semicircles above it. The sun also there rises and sets perpendicularly to the horizon. Hence, it is evident that the lengths of every arc described above the horizon are equal to those described below it, therefore at the equator the sun and the stars are visible as long as the time during which they are invisible, consequently the days and nights have an equal duration of 12 hours.

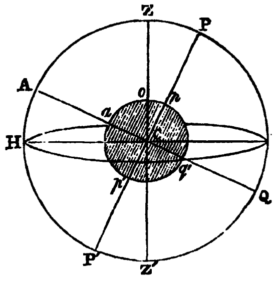


29.

Polar Altitude.

38. The distance of the north pole P (fig. 30) from the horizon H′ of an observer is called the *polar altitude* of the latter.

So, for instance, the polar altitude, viz., the height at which the pole-star at P appears to an observer at *o*, is expressed both by the arc P H′, and also by the angle P C H′.

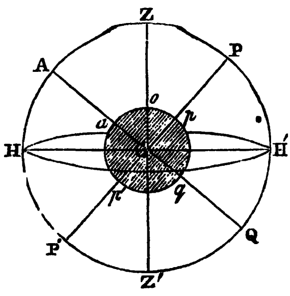


30.

By *equatorial altitude* is meant the distance of a star at A on the equinoctial from the horizon H of the observer, and is expressed both by the angle A C H, and also by the arc A H.

The arcs of the polar and equatorial altitudes of one and the same place make together always an arc of 90°, that is a quarter of a circle, or a quadrant. In London, for example, we see the pole-star is elevated to an angle of 51° 30′ above the horizon, which elevation we call its altitude. If we subtract this number from 90°, we find that 38° 30′ is the equatorial altitude of the place. Since the place does not change its relative position on the surface of the earth, the polar altitude remains always the same, that is, the pole-star is always at the same height from the horizon.

On the other hand, an *observer* can change his position on the earth. If, for example, he advances in the direction from *o* to *p*, the pole-star is more and more elevated to a greater height above his horizon, or, in other words, the polar altitude of the observer is increased in the same ratio as the equatorial altitude is diminished.



If he reaches *p*, viz., the north pole, his polar altitude is 90°, and the pole-star is in his zenith, whilst the equator coincides with his horizon, and consequently the equatorial altitude is zero. (See fig. 28.)

If, on the contrary, a journey be made in an opposite direction from *o* towards the equator *a*, the pole-star gradually descends towards the horizon, consequently the polar altitude continu-

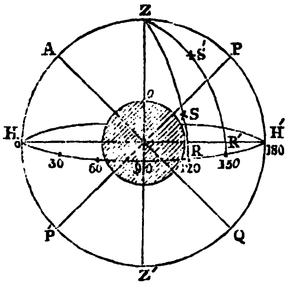
ally decreases in the same ratio as the equatorial altitude increases. When the traveller has arrived at the equator *a*, the polar altitude is = 0°, and the pole-star appears in the horizon, whilst the equinoctial is in his zenith. (See fig. 29.)

It is easily understood that the polar altitude, or the equatorial altitude of a place, is the same as we have already explained in § 26 to be its *latitude*, namely, the distance of it from the equator.

The fact that the polar altitude of a star increases or decreases, according as we approach the equator, or the north pole, is a striking proof of the spherical form of the earth.

Altitude of the Stars.

39. By the altitude of a star we understand its distance from the horizon of an observer. To express this altitude, *vertical circles* are employed, Z R and Z R′ (fig. 32), which are supposed to be drawn from the zenith through the stars S and S′ perpendicularly to the horizon H H′. The arcs S R and S′ R′ are therefore the altitudes of the stars S and S′ for the observer at *o*. The arcs S Z and S′ Z, which with the altitudes of the stars S and S′ make the quadrant or 90°, are called the *zenith distance* of these stars.



32.

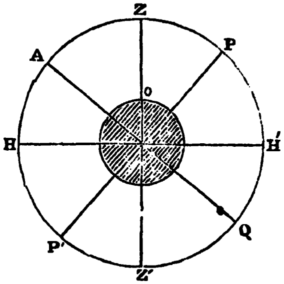
To define accurately the position of a star in reference to the horizon, the whole space from H south to H′ north, is divided into 180°, and the distance of the circles of altitude of a star from the south point, expressed in degrees, is called the *azimuth* of this star. Thus the azimuth of the star S is the arc R H = 120°, that of S′ is the arc R′ H = 150°. All stars that are on the same verticle circle have evidently the same azimuth; and, according to the side of the heavens on which the star is, the azimuth will be named either east or west.

The same star will appear at different altitudes if observed from different points of the earth at the same time. Consequently, if the altitude of a star at a given place and time is known by a voyager, he can, from the altitude of the same star observed from another place, find the situation of the position he is in. The determination of the altitudes of the heavenly bodies is of the utmost importance to seafaring men, who at an early period of their lives are trained to make these observations with accuracy and despatch.

Meridian.

40. If we suppose the circle Z H′ Z′ H Z (fig. 33) drawn through the zenith Z, and the nadir Z′ of the observer at *o*, and also through the celestial poles P and P′, this circle will represent the *meridian* or *noon circle* of the observer at *o*. This circle is so termed from the circumstance already stated (§ 33) that the observer has mid-day or noon when the sun enters it. At this moment the sun reaches his highest or culminating point; and when a star, or when several stars (for many stars may be supposed on the arc H A Z P), appear on the meridian, we name this their point of culmination.

In the diagram (fig. 33) the meridian is the only one of the celestial circles which lies in the plane of the paper, while the horizon, the equinoctial, and the vertical circles are to be imagined as projecting from this plane, which position is not easily represented. The plane of the meridian cuts the horizon of the observer at right angles in the line H H′, which has been already described (§ 32) as the *meridional line.* And as the polar altitude and the horizon are different for every place on the earth's surface, so every place has its own special meridian.



33.

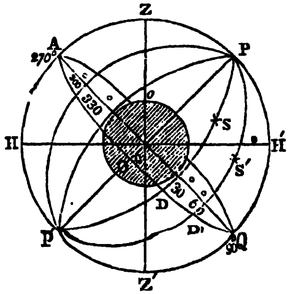
If, for instance, the observer at *o*, while contemplating the aspect of the nocturnal starry firmament, turns his back to the pole-star P, and looks exactly towards the south point H, he has thus placed himself in the direction of his own meridian. If in this position he observes a star which is on the meridian, this star by the rotation of the earth after some time will not remain on the meridian, but appear as proceeding towards the West, while other stars have entered the meridian. If the time of transit of a star through the meridian has been noted by the observer, he will find it on the meridian again exactly 24 hours afterwards.

On an artificial celestial globe the meridian is represented by a brass ring, in which the globe is moveable.

It is difficult to determine exactly by the eye the precise place of the meridian in the heavens. For more accurate observations a telescope is employed which is moveable around its small axis, so carefully adjusted that its longitudinal axis lies in the direction of the celestial meridian. Through this instrument the stars can be seen only during their transit through the meridian, and hence an instrument of this kind is called a meridian telescope or transit instrument.

41. All the lines and points hitherto named give the station of a star only for a definite place on the earth's surface. For the determination of a star's precise position in the heavens, other lines are drawn which always preserve the same place relative to the same star.

The equator is such a line. This indicates first of all whether a star is on the northern or southern hemisphere. Through the equator, commencing at the vernal equinox O, 180 circles are drawn which divide it into 360°. The distance of any such circle from the point O, is called the *right ascension* of a star which has its place in that circle. For example, the arc O D of 30°, and O D′ of 60°, are the right ascensions of the stars S and S′.



34.

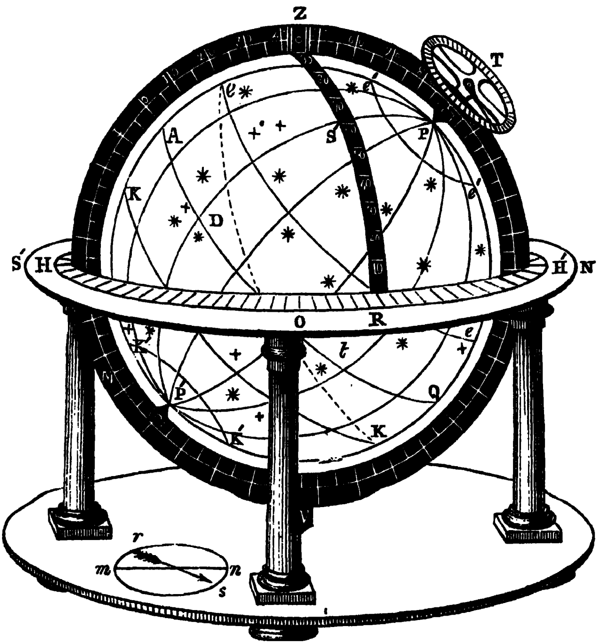
The distance of a star from the equator is called its *declination*, which is either North or South. The arcs D S and D′ S′ express the northern declination of the stars S S′. Hence all those circles drawn through the equator, viz., P D P′ and P D′ P′ are called *circles* of *declination.*

It may hence be observed, that the right ascension and declination of a star being known, its position on the celestial globe is readily found, in the same manner as places are found on the terrestrial globe by the longitude and latitude.

Celestial Globe.

42. We have in the preceding section named and described such a considerable number of points and lines, that it appears desirable to give a connected view of them. It is always difficult, and, in some cases, impossible, to represent those points and lines on the heavens, without some such aid as that which is afforded by a celestial globe. This may be obtained at every mapseller's from 4 to 36 inches in diameter, and at prices varying, according to the size and construction, from 5*s*. upwards; and though the larger are preferable, a very clear apprehension of astronomical phenomena may be acquired from the smaller-sized globes.

The best construction of a celestial globe would be that of a smaller ball which represents the earth, surrounded by a larger hemisphere representing the concave vault of heaven on which the stars and their courses might be described. Such a mechanical contrivance being impracticable, the student is to remember that his position is supposed to be in the interior of the globe upon a small terrestrial globe.



35.

43. Points and Lines on the Celestial Globe.

Z Zenith of the Observer (§ 27).
P North Pole (§ 31).
P′ South Pole.
S′ South (§ 32.)
N North.
O East.
(West, being opposite, is invisible.)
e e Northern Tropic of Cancer (§ 34).
K K Southern Tropic of Capricorn.
e′ e′ Northern Arctic Circle.
h′ k′ Southern Arctic Circle.
M Meridian of the Observer (§ 40).
T Horary Circle (§ 152).
P H′ Polar Altitude of the Observer (§ 38).

A H Equatorial Altitude of the Observer (§ 38).
P P′ Celestial Axis (§ 31).
A Q Equinoctial (§ 31).
H H′ Horizon (§ 29).
e K Ecliptic (§ 34).
S Star.
S R Height of the Star (§ 39).
S Z Zenith distance of the same (§ 39).
R H Azimuth of the same (§ 39).
S D North declination of the same (§ 41).
D A Right ascension of the same.
S P Polar distance of the same.

The celestial globe rests in the first place by two pivots fixed to its poles, P P′, in a brass ring, M, which represents the *meridian* of the observer, and which is about half a line distant from the surface of the globe, leaving it just sufficient space for free motion round its axis.

The meridian rests in suitable notches in a horizontal frame H H′ and in the support V which allow the globe as required to be placed in different positions relative to the horizon. The horizontal ring represents the true *horizon* of the observer.

From the point A of the *equinoctial* A Q, the meridian is divided both in the direction of the north and of the south pole, into 90°. The *declination* of a certain star is found on the meridian by bringing it under the meridian. In like manner the meridian is employed to place the globe in the polar altitude of the observer.

The *horizon* is divided from the southern point S′, into 360°; and on this the azimuth of a star is read off.

At the point Z of the meridian, which corresponds to the zenith of the observer, a brass quadrant Z R can be screwed, which rises from the horizon, and is divided into 90°: from this the altitude and zenith distance of a star is read off.

Above all things the globe must be placed in a position corresponding to the situation of the observer upon the earth; that is, the meridian of the globe H H′, must be in the meridional line of the observer, and the polar altitude P H′ must also correspond to that of the observer. The latter is very simple, for example, an inhabitant at the equator, the polar altitude of which is = 0° (§ 37), rectifies the globe, so that both the poles, P P′, lie in the plane of the equator. In the neighbourhood of London the globe is to be placed or rectified, so that the arc P H′, the height of the pole above the horizon, may be 51° 30′.

We determine the meridional line of the observer by the compass which for this purpose is appended to every large globe. For example, we draw on the base or pedestal of the globe the line *m n* parallel with the meridian H H′ of the globe, and place on this line, so drawn, the magnetic needle *r s*, the point of which assumes a northerly direction. We then turn the pedestal of the globe till the line *m n* coincides with the needle. It has been, however, shown in our Physical section (§ 197), that the direction of the needle is not exactly north, but varies somewhat from it. We correct this variation of the needle

by turning the pedestal till the needle makes an angle with the line *m n* of 18°, which is the amount of the westerly variation of the needle; and consequently the line *m n* is now exactly in a northerly direction, and is parallel with the meridian H H′.

44. Another contrivance appended to the globe is the *horary circle* T (fig. 35), which is divided into 24 equal parts or hours, corresponding to the 24 hours of day and night. The horary circle is immoveable, but through its centre passes a prolongation of the axis of the globe to which an index is fastened, and which passes over a space on the ring as soon as the globe is turned round. If the globe makes a complete rotation, and therefore the 360 degrees of the equator pass under the meridian, the index also describes the whole circle of 24 hours, consequently the globe makes, for every hour which the index traverses, a rotation of 15 degrees. The index, however, is not of the same piece as the axis, but can be turned round it by means of a screw or other suitable contrivance in such a manner that the hand can be pointed to any number of the horary circle without at the same time turning the globe. The importance of the horary circle for the use of the globe will immediately become evident by its application.

After the globe is put in a correct position in relation to the polar altitude and cardinal points, it must be placed in a situation corresponding to the time of observation in reference to the stars which are then visible. This will be rendered clear by the following observations:—Every day at 12 o'clock the sun stands in the meridian of the observer (see § 40), hence we first bring that point of the globe under the brass meridian on which the sun stands at 12 o'clock at noon. This point is of course situated on the ecliptic, and in the beginning of spring on the 21st of March at the point whence the ecliptic intersects the equator, from which point the latter is divided into 360 degrees. On every following day the sun travels almost exactly one degree farther, as, for example, after the lapse of 204 days, that is in the middle of October, the straight *ascension* of the sun (§ 41), that is its distance from the vernal point, amounts to 204 degrees. If, therefore, we bring this degree of the equator under the meridian, the position at which the latter intersects the ecliptic is the position of the sun at mid-day.

The hand of the horary circle is now placed upon the one number 12, and the globe turned round till the hand points to the other number 12, making thus half a revolution. All the constellations on the globe have now the position which the stars occupy at midnight at the place of the observer. For example, we thus find that at this hour, the constellation of *Cassiopeia* is in the meridian. If we afterwards turn the globe to the right or left, the hand can be brought upon every hour desired before or after midnight, in which case the stars then visible present themselves on the globe.

Numerous problems, which suggest themselves to the student, or which are found in the small treatises sold by the mapsellers, may be solved by the aid of the celestial globe.

In the commencement there is some little difficulty to transfer the picture of the heavens to the globe and *vice versâ*. The student must suppose himself to be in the centre of the globe, and from thence imagine straight lines drawn through the stars which are represented on the globe, and prolonged to the heavens where they will reach the corresponding stars.

It is best for the student to commence his observations in the twilight of evening or on moonlight nights, because then the larger and more conspicuous stars are visible, so that he is not confused by the large number of stars which are visible on dark nights. When the larger stars are known, the smaller are easily found.

(C.) CLASSIFICATION OF THE HEAVENLY BODIES.

45. Of all the celestial bodies, the *sun*, this brilliant star of day, and the *moon*, distinguished by the changeableness of her form, merit our special consideration.

These two celestial bodies, by their apparent magnitude, present themselves amongst the other stars as universal lords, an idea which, however long it may have prevailed, has been materially injured by the observations of astronomy.

Also, amongst the stars themselves, we find by accurate observation many differences. We perceive that by far the greater number of the stars appear to us always to occupy the same points of the firmament, when we observe them at the same stated times; and it is on this account that they have received the name of *fixed stars*.

Some stars change their positions in the heavens so remarkably, that at definite periods they occupy certain particular positions, being sometimes to be seen in one, sometimes in another quarter of the heavens: these were hence named wandering stars, or *planets*. The number of these stars or planets at present known is only twenty-one.

Finally, the *comets* are still more remarkable, both by their being accompanied by a more or less extended luminous appendage, which follows the star like a tail, and by the changes of position, which are still more considerable than those of the planets, since some comets often suddenly appear and again disappear, and others only present themselves again after the lapse of a great many years.

We shall commence with a description of the fixed stars, these being most important for the geography of the heavens. We will afterwards explain the relation of the earth to the sun and moon as being of particular importance regarding time and climate, and, finally, through the study of the planets and comets pass to a more general consideration of the arrangement of the universe.

Fixed Stars.

46. By successive and repeated observations of the fixed stars, with the assistance of the globe and star charts, we readily acquire a facility in finding their places in the firmament. We observe, furthermore, that these bodies, otherwise a maze of complicity, are grouped or arranged in a very definite manner, with which we gradually become so familiar, that the least change of the heavenly bodies cannot escape us.

When the sun disappears below the horizon, the stars appear as so many sparkling points, dispersed here and there, through the spacious firmament, during the continuance of twilight. Their number is increased with the increasing darkness; and, by the assistance of a telescope, myriads are observable in the immense incomprehensible regions of space. Places which to the unassisted eye appear only like nebulous spots or streaks, by the armed eye are

distinctly recognised as groups of countless stars; and the *Milky Way*, as it is termed, is found to be composed of countless millions of such bodies.

The apparent magnitude of the stars is very different. Whilst some glisten and shine with a lustre which far surpasses others, some can scarcely be recognised as luminous points. By their apparent magnitudes, as visible to the unassisted eye, the stars are divided into six classes. There are 18 stars of the first magnitude, 60 of the second, 200 of the third, 380 of the fourth, and with the two following classes, in all about 5,000; of telescopic stars about 70,000 have been observed; and from reasons which cannot be here stated, the probable number of stars in the universe is estimated at 500,000 millions.

The fixed stars appear, even through the most powerful telescopes, invariably as small luminous points: hence we may judge of their enormous distances. This is confirmed by another circumstance, viz., that two stars of proximate mutual distance always appear to us equally distant from whatever part of the earth's orbit they may be observed. Although the most distant points of the earth's orbit are 195 millions of miles asunder, it is possible to ascertain, with certainty, the parallax of only a few of the fixed stars; that is, the angle of vision under which the semi-diameter of the earth's orbit = $97\frac{1}{2}$ millions of miles, would appear to an eye placed on one of the fixed stars. The merit of the greatest exactness in determining the parallax of the fixed stars is awarded to the observations of the renowned astronomer, Bessel,* of Königsburg, who succeeded in ascertaining the parallax of No. 61 in the constellation of the Swan; which is found to be 0·3136 second. By this parallax the sun's mean distance from this star, 61 of the Swan, is calculated to be nearly 62,672,712 millions of miles. Light, which moves at the rate of 195,000 miles in a second, would require $10\frac{3}{10}$ years to pass through this space; and a locomotive steam-engine, which travels at the rate of 920 miles per day, would be 200 millions of years in reaching this star.

A stellar parallax, greater than a second, has not yet been accurately determined. Hence it is a well-founded assumption that the nearest of the fixed stars is 200,000 times farther from the earth than the sun; consequently, about 19 billions of miles is the assumed distance of the nearest fixed star from the earth.

To conceive such a stellar distance surpasses the utmost range of human imagination, and to form any adequate conception of this enormous extent of space is utterly impossible; but we may approximate to a somewhat clear apprehension by comparison. Light, as above stated, moves with the celerity of 195,000 miles in a second; yet three years, at least, would elapse ere light from the nearest of the fixed stars could reach the earth.

This is by no means the utmost extent of the distances of bodies in celestial space. On the contrary, it has been assumed, with feasibility, that stars have been observed, the distances of which amount to $1\frac{1}{2}$ million times that of the sun, and the light from which would be many years in reaching our earth.

* *Bessel*, the Professor of Astronomy at Königsburg, was born at Minden in 1784, and died in 1846. To great natural powers of observation he united the rare and profound knowledge of theoretical mathematics, which he applied, in a way hitherto unknown, to the reduction of errors in the results of observations, surpassing in accuracy all that had been accomplished before his time. In this respect he will be regarded as an example to the astronomers of all subsequent ages.

It may naturally be assumed that bodies, which are visible at such inconceivable distances, are also of enormously great magnitude; and we are justified in assuming that none of the fixed stars are in this respect inferior to the sun, and that most of them surpass him in magnitude.

Stars visible in Europe.

47. Even in the earliest ages stars that appeared to be in close proximity were grouped together, and by the aid of a lively fancy their outline was supposed to resemble certain well-known objects. Hence originated the names of the constellations. The seven stars of the Great Bear were sometimes called Charles's Wain, the Plough of the North, &c. In most of the constellations, however, a wide field is left to the imagination, for it is seldom that we are enabled to discover any relation between the outlines of the groups and their names.

48. The eye directed towards the heavens does not at every place and at all times perceive the same stars; but, on the contrary, essential differences in the appearance of the heavens are observed according to the point of the earth and to the season and hour at which the observation is made. An observer at the north pole has in his zenith the *pole-star*, and he sees from there the whole northern hemisphere, and consequently all its stars. An inhabitant at the equator sees half the northern and half the southern hemispheres of the heavens, and the pole-star appears to him in the horizon.

The greater number of Europeans dwell between the 40th and 70th degrees of north latitude, and to them all the stars of the northern and more or less of the stars of the southern hemisphere are visible according as they are more or less distant from the equator.

Under all circumstances, we never perceive at the same time more than half of the starry heavens; but it is easy to imagine that, after a time, we see a greater number of stars, in consequence of the rotation of the earth, since there are continually stars setting in the west and others rising in the east.

49. We will now pass to the consideration of the constellations, and it is best to commence with those which are near the pole-star, and which are visible every evening and during the whole night, since they never set.

It is most convenient to proceed from the *Great Bear*, because this is the most remarkable group of stars, which every one is acquainted with, even those who are not engaged in the study of astronomy. It consists of seven stars, six of which are of the second magnitude; four of them form a square, the other three stand in an arc in the tail of the Bear. If we imagine a line drawn through the two latter stars of the Bear, its prolongation will reach a star of the second magnitude standing alone, and which is the pole-star belonging to the Little Bear. The importance of this star has already been several times mentioned; as it is only $1\frac{2}{3}$ degree distant from the pole, it may be regarded as the point around which the whole hemisphere of the heavens turns.

One of the most extensive constellations is the *Dragon*, which winds itself around the Bear, and is formed of many stars of the third and fourth magnitude, which define nearly half the polar circle. Opposite to the Great Bear, on the other side of the pole, we perceive five stars of the second and third magnitude, forming a W. This constellation, half of which is in the Milky Way, is called *Cassiopeia*. If we unite this group of stars with the Great

Bear by a line, and draw through the middle of this another line at right angles, we see on the right hand of this line *Capella*, a star of the first magnitude, in the constellation of the *Waggoner*, and on the left hand *Weger* of *Lyra*, which is also of the first magnitude.

Of the other groups worthy of mention situated within the Tropic of Cancer we may mention *Bootes*, in which is *Arcturius*, shining as a star of the first magnitude, and to which a straight line drawn through the two lower stars of the Great Bear leads. Near to Cassiopeia is *Perseus*, with a star of the second magnitude, standing on a brilliant part of the Milky Way. From this we readily find the three bright stars of *Andromeda*, as well as *Perseus*, recognisable by four stars of the second magnitude, forming a square.

Constellations of the Ecliptic.

50. We now come to a portion of the heavens which is bounded by the two tropics, and which is of especial interest, since within these limits we find the constellations of the ecliptic.

Of all the celestial zones, or circles, the ecliptic is the only one which we find distinguished in the firmament by a series of constellations. The ecliptic has been divided into twelve equal divisions by twelve constellations, or signs, supposed to be equally distant; and each constellation contains 30°, the circle being divided, as usual, into 360°. As we shall subsequently have to consider the important relations of these constellations to ourselves, we shall, for the present, only give their names and characteristic signs. Since the equator cuts the ecliptic in two points, one of these two sections is on the north and the other on the south hemisphere of heaven. Hence we divide the constellations of the ecliptic, or signs of the zodiac, as they are commonly called, into the northern and southern constellations, and supply their names and ancient marks, or signs, as under.

I. Northern Constellations of the Zodiac.			II. Southern Constellations of the Zodiac.		
1. The Ram	♈	Aries.	7. The Balance	♎	Libra.
2. The Bull	♉	Taurus	8. The Scorpion	♏	Scorpio.
3. The Twins	♊	Gemini	9. The Archer	♐	Saggitarius.
4. The Crab	♋	Cancer.	10. The Goat	♑	Capricornus.
5. The Lion	♌	Leo.	11. The Water-bearer	♒	Aquarius.
8. The Virgin	♍	Virgo.	12. The Fishes	♓	Pisces.

As an illustration of the position of the ecliptic in the heavens, we refer to the diagram of the celestial globe.

We commence with the northern constellations of the ecliptic at the vernal equinox, viz., where the ecliptic cuts the equator, and the first is the *Ram*, known by the three large stars in the head; the brightest is of the second magnitude. Next follows the *Bull*, under Perseus and the Waggoner (Auriga), easily known by the V, which is formed by a group of four stars in the Bull's head, and called the *Hyades*, or the rainy stars. The star of the first magnitude at the upper end of the V, to the left, is *Aldebaran*. On the back of the Bull are seen the Pleiades, a group of small stars, very close together.

In the *Twins* the ecliptic reaches its greatest northern altitude. We perceive

two bright stars of the second magnitude, *Castor* and *Pollux*, in the head of the constellation, and four stars of the third magnitude at the feet forming together an oblong.

This region of the heavens is distinguished by remarkable brilliancy, owing to the proximity of several constellations, amongst which we notice *Orion*, the most beautiful of all the stars which is placed on the southern side beneath the Bull and the Twins. Two stars of the first magnitude especially attract our notice, these are *Beteigeuze* on the east shoulder, and *Rigel* on the west foot. Between these stars three others of the second magnitude, standing together, form the girdle of *Orion*, which is also termed *Jacob's Staff*. Near to the girdle we notice the remarkable nebulous spot of Orion. *Beteigeuze* forms with two other stars of the first magnitude a regular triangle, namely, with *Procyon* of the *Little Dog*, and with *Sirius*, the most lustrous of stars, standing at the head of the Great Dog, and hence it is also called the *Dog-star*. This constellation can be seen during the dog-days (from July to August) rising and setting with the sun, which at this season of the year has reached his greatest height, and therefore diffuses the greatest heat.

The direction of the ecliptic is now through the invisible constellation of the *Crab*, composed of faintly-glimmering stars, to the *Lion*, distinguished by four principal stars forming a large trapezium :: (figure of four sides), of which *Regulus*, the chief ornament of this constellation, is a star of the first magnitude. Next succeeds the *Virgin*, conspicuous for five stars, forming an anchor with rectangular flukes, and also for the star of the first magnitude called the ear of corn of the Virgin (Spica Virginis).

Here the ecliptic is again cut by the equator, and we now descend to the southern constellations, where we first meet with the *Balance*, with four stars, which form a pretty regular square.

In the *Scorpion*, Antares appears as a star of the first magnitude, which the *Archer* follows, visible only in the lower part of the southern horizon: it is easily recognised by four stars, forming a rectangular figure. The ecliptic here has reached its most southern declination, and recommences its ascending course to the equator, meeting first the constellation of the *Goat* under the *Eagle*, distinguished by *Atair*, a star of the first magnitude, and the *Water-bearer*, easily known by two stars on his shoulders, and three at some distance to the south-east of the former.

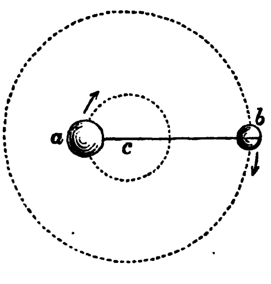
The *Fishes* conclude the orbitual path of the sun round the vault of heaven. This sign contains no remarkable star, and its position is most easily determined by Pegasus, below which it is situated. But between the water-bearer and the fishes, and lower in the south, is Fomahand, a star of the first magnitude in the constellation of the southern fishes.

III. SPECIAL ASTRONOMICAL PHENOMENA.

Sun and Earth.

50. Suppose on the two ends of a rod there be fixed two balls, *a* and *b*, fig. 36, and the ball *a* to be three times the magnitude of the ball *b*; the centre of gravitation must be, consequently, nearer the greater magnitude: and from Physical section, (§ 47), we know that if we divide the distance between the centres of the two balls into four equal parts, the common centre of gravitation

lies at one-quarter of the distance, namely at c. Then if we multiply the distance 3 by the mass $b = 1$, we have 3; and if we again multiply the mass 3 by the distance 1, we have the same result; and hence the two bodies, if supported at c, will be in equilibrium. If we suppose these two bodies in motion round the centre of gravitation, we see in the dotted lines the orbits described by both balls, and also that the smaller mass, b, describes a circle round the larger mass a.



36.

If we throw into the atmosphere two unequal masses similarly connected, we shall find that they assume a rotatory motion around their common centre of gravitation, and the smaller mass constantly describes an orbit around the larger.

If, in the example fig. 36, the mass of the ball a were ten times or a hundred times the mass of b, the common centre of gravitation would fall within the greater ball; and we should find that this ball would describe a circle round a point in the interior of itself, whilst the smaller ball would describe a circle round the greater.

52. The sun and the earth are two bodies or masses of a spherical shape, and have similar relations to each other as the two masses, fig. 36, only their difference is much greater, as the following table shows:—

TABLE of the RELATIVE MAGNITUDES of the SUN and EARTH.

		Earth.	Sun.	Ratio of the Earth to the Sun.	
Diameter	Miles	7,926	887,680	1	112
Surface	Square Miles	197,336,595	2,296,080,000,000	1	12,577
Contents	Cubic Miles	260,692,177,925	399,815,355,000,000	1	1,410,000
Mean Distance	Miles	95,447,700	. . .	.	. .
	Radii of the Earth	24,000	. . .	.	. .

If we imagine these two bodies to be connected by any means whatever, their common centre of gravitation would fall within the body of the sun, and in truth very near to its centre. If these were slung into the immensity of space, they would describe revolutions like the balls in the above example, the sun about his own axis, and the earth in an orbit round the sun.

This is actually the case, although the sun and earth are not connected by any material bond, like the bodies in the example, but by a peculiar combination of forces.

The force which maintains the connection of the sun and the earth, is the mutual attraction which affects all bodies, and which we have already, in Physics, explained as the force of gravitation.

That the sun and earth preserve their respective distances, and do not progressively approach each other till a collision takes place, is owing to the operation of a second force, which acts at right angles to the gravitating tendency, and produces the compound motion of the earth. (Comp. Phys., § 52.)

53. The enormous mass of the body of the sun is not without motion. We perceive this by means of certain dark places on the luminous surface of the sun, and which we call *spots* on the sun's disc. These do not always appear in the same places. For it has been observed that they traverse the sun's disc from the one margin to the other, where they finally disappear; thus passing over the opposite surface of the sun, they emerge again, after some time, on the same part of his margin, where they first appeared. This phenomenon proves that the sun revolves on its axis; and the time elapsing during one rotation, is twenty-five days and a half, while the earth's rotation is completed in one day.

It is a difficult matter to explain the cause of the dazzling brightness and of the reanimating heat which proceed from the sun. The assumption that the sun is a burning body, in a chemical sense, is untenable. Every body constantly emitting light and heat by combustion is liable to a continual decrease; and this must have happened to the sun in a sensible degree, notwithstanding the prodigious immensity of its bulk. But, on the contrary, the sun appears to be the source of an unvarying amount of light and heat.

It is the opinion of most philosophers that the sun is a dark body, surrounded by a peculiar atmosphere, which is kept in a state of continual vibration by the enormous velocity of the sun's revolution, and thus becomes evident to us as light and warmth. Sometimes there are to be seen breaks, originating in unknown causes, in the sun's atmosphere, and through these breaks or chasms, which we call spots, we can see the dark body of the sun.

That friction can be a source of light and heat, some well-known phenomena testify. Let, for example, a piston which tightly fits a cylindrical tube, be pressed down the tube rapidly and forcibly, both light and heat will be generated at the same time, and the last in sufficient quantity to kindle tinder, if attached to the end of the piston. This apparatus is called a *pneumatic tinder-box*. We also find that when mercury is shaken in an exhausted glass tube, it produces a vivid light; and from these facts it may be concluded, that it is possible that light and heat may be produced without adopting an assumption contradicted by all our experience of terrestrial bodies.

54. The path in which the earth moves, in its course round the sun, is an *ellipse* (§ 13) of very small excentricity, approaching almost to a circle. The long axis, or line of the *apsides*, is 189,051,000 of miles. In one of the foci is the sun, and the earth reaches its greatest distance from this luminary, when it is at the one end of the axis of the ecliptic, where the distance is 96,969,583 miles, which is on the 2nd of July. This point is the sun's greatest distance, or as it is called, *aphelion*. On the opposite point of the great axis of the ecliptic, the earth reaches the point nearest to the sun, or its *perihelion*, on the 1st January, when it is 93,763,878 miles distant from the sun. By taking the half sum of the greater and less distance of the earth from the sun, we ascertain the mean distance of these two bodies to be 95,447,700 miles.

The earth's orbit may in most cases be considered circular without occasioning any sensible error. Its semi-diameter would hence be 94,200,000, and its circumference about 585,597,000 miles; and this space is traversed by the earth in 365 days and a few hours: consequently the earth traverses a space of eighteen miles and a half in a second. Hence, the velocity of the earth's orbitual motion is much greater than the velocity of its diurnal motion, which at a

point in the equator, is only at the rate of about 1,430 feet in a second. If we could travel with a velocity equal to that of the earth's orbitual motion, we might accomplish a journey round the earth of 24,849 miles in twenty-two minutes and a half.

This assigned velocity is only the *mean* of the earth's actual velocity. The elliptic figure of its orbit has an essential influence in modifying it, either retarding or accelerating: the celerity is augmented when the earth is approaching its perihelion, and is retarded while drawing towards its aphelion. From this circumstance, as will be hereafter shown, there is a difference between the duration of the summer and winter half-years, the former being seven days and three-quarters longer than the latter.

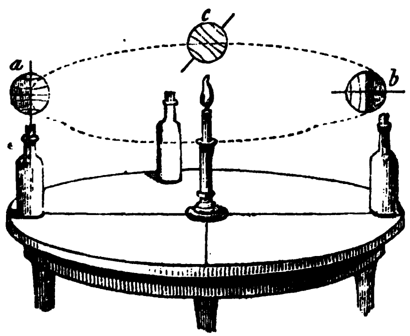
Position of the Earth's axis to the plane of the Earth's orbit.

55. We suppose a plane passing through the centre of the sun, and extended on all sides, having the earth moving within it. This may be represented by a round piece of pasteboard having a circular and central hole into which a small ball may be half inserted. This ball or globe represents the sun; the flat pasteboard represents the plane of the earth's orbit, which can be described on the paper by a circle having the sun for its centre. The earth itself may also be represented by a smaller ball inserted in a similar circular hole, or into several made in different parts of its orbit.

It is very difficult, in some cases impossible, to illustrate satisfactorily the phenomena, to be described in the following paragraphs, by means of diagrams alone. These are only calculated to represent objects that are adequately illustrated on a flat surface; but many of the phenomena of motion can only be explained by a model which cannot be conveniently represented by a diagram.

If we describe on a small ball, which represents the earth, the usual circles, viz., the equator, the tropical, and the polar circles, together with the poles themselves, it is easy to perceive that we can give to this ball very different positions to the plane of the earth's orbit. We may place it so that both poles, and consequently the earth's axis, may be in the plane of its orbit; or it may be placed with its axis perpendicular to the plane; and, finally, it may be made to assume an oblique position to it, so that its axis may make an acute angle with the plane of the orbit.

It is now to be shown that these three different positions produce most important changes upon the phenomena observable on the earth's surface. The comprehension is much aided by placing a light to represent the sun on the centre of a round table. On the margin of the table, at an equal height with the flame, we place a small globe, whose axis may be made to assume any one of the three above-mentioned positions. Instead of a globe, a little wooden ball may be used, moveable about a knitting needle, which serves for its axis. The needle



38.

may be elevated to the same height as the candle, by being stuck into a cork in a bottle, and it may be either perpendicular to, or parallel with, or inclined to the plane of the table. The requisite parallel circles and the equator are described on the ball. Finally, the circumference of the table is divided into four equal portions by two lines intersecting each other at right angles in the centre. With the aid of this simple arrangement, the following statements will be more easily and clearly comprehended than they could be by any diagrams whatever.

56. In the first place we assume that the earth's axis is perpendicular to the plane of its orbit, as in *a*, fig. 38.

In this condition, every portion of the earth during the whole year, would have the duration of the days and nights equal. The sun's rays falling thus perpendicularly on the equator, would burn up the regions situated near it, and render them uninhabitable. The countries situated between the circles somewhat more distant from the equator would be more fortunate, since in consequence of the oblique direction of the sun's rays they would enjoy the temperature of a mild spring, which would be continuous during the whole year. But the inhabitants of those countries would be deprived of the charms of the successive changes of season which we enjoy. Many plants could not reach their full development under these circumstances. But the condition of the regions at a considerable distance from the equator, or near the poles, would be very dismal. Partly on account of the obliquity of the sun's rays, and partly through their interception, an eternal winter and continual desolation would be prevalent in countries where millions of human beings now lead comfortable and happy lives. If, therefore, the earth's axis were placed perpendicularly to its orbit, the greater portion of its surface would be an uninhabitable desert.

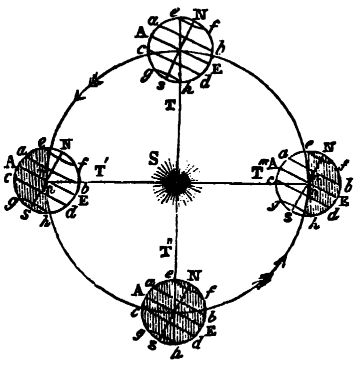
Still more conspicuous phenomena would be produced, if the axis of the earth, as in *b*, fig. 38, were parallel to its orbit, so that its poles continually remain in the same direction. In this case the entire northern hemisphere would be enlightened once a year; the light would fall perpendicularly upon the north pole, and the day would be 24 hours long. On the opposite side, at *a*, the southern hemisphere would be enlightened and heated in a similar way; and a sharp alternation of heat and cold would be the result, unmitigated by the gradations which are actually experienced. This would render the earth a far more incommodious habitation than it would be under the former supposition.

It is well known that our earth neither has that uniformity of light and heat which would be occasioned by the perpendicularity of its axis, nor that abrupt change which would be the consequence of its parallel position to the plane of its orbit; hence, its inclination to its orbit must be an acute angle. (Comp. *c*, fig. 38.)

This is really the case, and hereby we are in a condition to explain a series of phenomena which are as important as they are well known.

57. Let us now consider the earth in its four principal positions relatively to the sun. In fig. 39, S is the sun, T the earth, the axis of which, *s* N, in all the representations remains parallel. It is evident, that only that portion of the earth which is opposite to the sun can receive the benefit of his light and warmth: the shaded portions represent the dark sides, and the unshaded the *enlightened halves* of the globe in these positions. T represents the position of

the earth on the 21st of March, when the sun's rays fall perpendicularly on the equator. In this case the circle of illumination passes through both the poles *s* and N, consequently there is day both on half the northern and half of the southern hemispheres at the same time; and as the earth turns on its axis *s* N, every part of its surface describes one-half of its daily rotation by day, and the other half by night. While the earth is in this portion of her orbit, the day and night are equal all over the earth, and hence its name *vernal equinox* (spring equal night). The same phenomenon appears at the *autumnal equinox*, represented by T″, where the diagram represents the unenlightened, or night appearance of the earth.



93.

When the earth in her course has traversed the next quadrant of her orbit, on the 21st of June she enters the *summer solstice*, T′. We perceive that the north pole, N, and a considerable part of the earth's surface contiguous to it, remains enlightened during the entire daily rotation of the earth round its axis. Within the north polar circle, *e f*, at the latitude of 66½°, or 23½° from the pole, the sun shines for 24 hours, and the nearer the pole the longer is the duration of sunshine. The portion lying in a higher latitude than 66½° is named the northern polar, or arctic, or frigid zone.

The reverse of all this occurs at the southern polar zone, *g h*, where, on the same day, the sun is not visible, but the night lasts for 24 hours.

On the equator the duration of both day and night is equal; for the illuminated portion *n* E, of this circle is equal to the darkened portion *n* A. On every point north of the equator the day will be longer than the night, since the illuminated portion *m b*, of the parallel circle *a b*, is evidently greater than the unenlightened portion *m a*; consequently, an inhabitant of this region will be longer in the illuminated than in the darkened part during the earth's diurnal rotation. All who live on the northern side of the equator have, on the 21st of June, their longest day and their shortest night.

That phenomena, in direct contrast to the above, should occur on the southern side of the equator, may easily be conceived.

The parallel circle, *a b*, on which the sun's rays fall perpendicularly on the 21st of June, is called the *tropic of Cancer*. Whilst the earth continues its orbitual course, the length of the days gradually decreases; and when, on the 23rd of September, she enters the *autumnal equinox*, T″, day and night are again equal. From this point by farther progression, the day is continually shortened, till, on the 21st of December, the earth has reached the *winter solstice*, T‴, where the sun is perpendicular to the *tropic of Capricorn*, *c d*. Here the diurnal arcs *m a* are evidently shorter than the nocturnal arcs *m b*, to all the inhabitants of the northern hemisphere. We have at this season our shortest days and longest nights; and our antipodes in the southern hemisphere enjoy their longest days.

TABLE of POLAR ALTITUDE and DURATION of SOLAR LIGHT.

Polar Altitude.	Duration of the Longest Day.
0° 0′	12 hours.
16 44	13 ,,
30 48	14 ,,
49 22	16 ,,
63 23	20 ,,
66 32	24 ,,
67 23	1 month.
73 39	3 months.
90 0	6 ,,

From the winter solstice to the vernal equinox, the day constantly increases and the night decreases; until at the latter point they are again equal.

Thus we see that, on this obliquity of the earth's axis to the plane of its orbit, the *apparent* annual course of the sun, its passage across the equator twice a-year, and progress to the tropics, described in § 34, can be explained.

The greatest altitude and declination of the sun is indicated by the tropical circles, which are 23½° north and south of the equator; because in these points the farther progress of the sun is arrested, and his subsequent progress is backwards to the equator.

58. To the inhabitants of the regions of the earth lying on each side of the equator, and within the tropics, called the tropical or torrid zone, the sun during the whole year is either perpendicular, or almost perpendicular. Hence they have greater heat and less diversity of season than the inhabitants of other portions of the globe. Plants and animals, even man himself, under the united effects of light and heat, assume peculiar forms and qualities.

Between the tropics and polar circles, on both sides of the equator, are situated the two *temperate zones*. In these regions the sun's rays never fall perpendicularly on the earth; and some portion of their calorific power is not absorbed, but reflected, and the temperature never reaches the maximum.

The entire surface of the torrid zone is estimated at 68½ millions of square miles; the two temperate zones at 102 millions; and the two frigid zones at 17 millions of square miles.

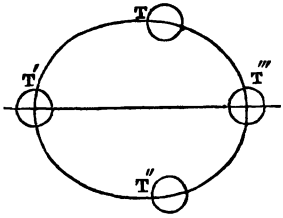
In the course of the year, the effects of the sun upon our northern temperate zone, *a b e f* (fig. 39), are very dissimilar. During the summer solstice (at T′), the sun's rays meet the earth at a much less oblique angle than at the time of the winter solstice, when the sun is on the southern side of the equator, and when his rays fall so obliquely that a large portion of their calorific influence is intercepted and dissipated in the surrounding atmosphere. Besides this, there is the longer duration of the sun above our horizon, and consequently a greater absorption of heat by the surface of the ground. This is the cause of the great range of temperature experienced by us in the space of a year; hence the change of seasons, the transition from an ungenial season to the mild expansive influence of spring, followed by the ripening warmth of summer, when finally the autumn, with a decrease of both light and heat, opens the gate to icy winter.

What advantages, what attractions for mankind, are connected with this perpetual change of season! what an endless variety of charms to awake our attention and to excite our gratitude! The loveliness of flowery spring, the

glowing splendour of summer, the exuberance of autumn, and the stern uniformity of winter, have been the subjects of painting and poetry from the earliest ages to the present day.

59. Were the earth's orbit actually a circle, as in fig. 39, the periods between the equinoxes and solstices would be exactly equal; and the summer half-year from the vernal to the autumnal equinox would be of the same duration as the winter half-year.

This, however, is not the case; and the reason is, that the earth's orbit is elliptical, and the sun's place is in one of its foci.



40.

If T and T″ (fig. 40) are the equinoctial points, the portion of the arc of the winter half-year, T T‴ T″, lying between the two, is smaller than that portion of the orbit of the summer half-year, T T′ T″; and besides this, the velocity of the earth, in the winter portion of her orbit, is greater than in the other portion, because the earth is then nearer to the sun. Both causes co-operate; and their united effect is, that the summer half-year is 186 days and 12 hours long, and the winter half-year consists of only 178 days and 18 hours; consequently, the former is longer than the latter by 7¾ days.

Though the perihelion falls in mid-winter, and we are then 3,205,705 miles nearer the sun than we are at the time of the summer solstice, this greater proximity has no effect on the temperature of the earth's surface, being modified by the greater obliquity of the sun's rays and the shortness of the days, as has already been shown.

60. Suppose we observe the setting of the sun, on any evening, and remark at the same time the position of a star or of a constellation near the place where the sun disappeared below the horizon, on the following evening we shall perceive the same star or constellation in the same position near which we perceive the sun set. If, however, this observation is repeated or continued for several days, we may perceive that the sun approaches nearer to the star; and subsequently the latter sets at the same time as the sun, and is not of course perceptible after sunset. The same observation with another star may be repeated in a similar manner. On the eastern part of the horizon, also, we find a similar phenomenon. A star as near as possible to the sun, and which rises only a short time before him, will, after several days, rise earlier and be at a greater distance because the sun has travelled from it. Thus, we may observe the perpetual progression of the sun among the fixed stars from the west to the east, and we can describe his path when we remark the constellations in the vicinity of which he appears or disappears.

These constellations compose a *girdle* or zone among the fixed stars, so named probably from *ζώννυμι*, *I girdle*, or from *ζῶον*, *a living creature*, because most of the constellations of the *Zodiac*, bear the names of animals. The zodiac, or constellations of the ecliptic, is bounded by two parallel circles of from seven to eight degrees' distance from the ecliptic. When the sun appears in the neighbourhood of one of these constellations, we say that *he is in that constellation.* By twelve equally-distant constellations, the names and signs of which we have given in § 49, the ancients divided the zodiac into twelve equal

portions. The sun passes from one constellation of the zodiac to another, a distance of 30°, in the space of from 28 to 31 days, which is called a *month.* After the sun has completed his course in the space of twelve months from one constellation to another, he appears again in the constellation where he was first observed; and this revolution completes the year. During every successive month the sun is in another constellation.

About 3,000 years since, when the zodiac was assumed, the sun at the vernal equinox was in the constellation of the Ram (Aries), and the succeeding months with their constellations were as follow :—

March -	Aries, the Ram.	September -	Libra, the Balance.
April - -	Taurus, the Bull.	October -	Scorpio, the Scorpion.
May - -	Gemini, the Twins.	November -	Sagittarius, the Archer.
June - -	Cancer, the Crab.	December -	Capricornus, the Goat.
July - -	Leo, the Lion.	January -	Aquarius, the Waterbearer.
August -	Virgo, the Virgin.	February -	Pisces, the Fishes.

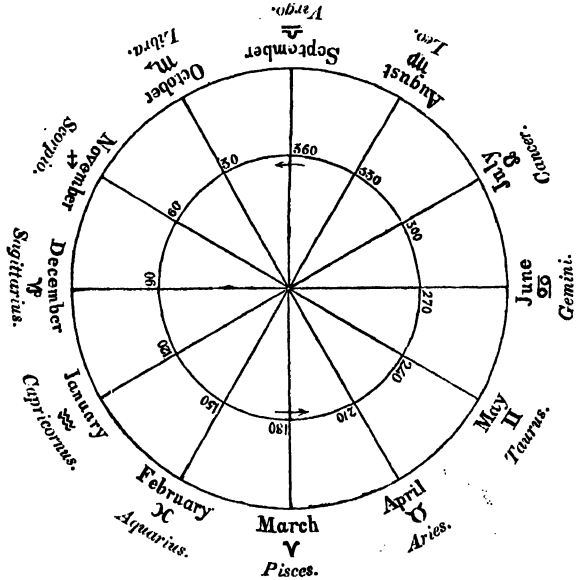
In consequence of a slow retrogression of the nodal point where the ecliptic and the equinoctial cut each other (called the *precession* of the equinoxes), this relation between the sun's actual course and the constellations has been altered. The sun, for example, is not in Aries on the 21st of March, but in the constellation of Pisces ; and also in the succeeding months the sun is in the constellation corresponding to the preceding sign. In order to avoid confusion, the ancient signs are still placed on celestial charts and globes; and a distinction is made between the *constellation* and its *sign* or mark. The latter are nothing but twelve marks, by which the ecliptic is divided; the former are the actual groups of stars. If, for example, the sun or a planet is said to be in the sign of the Crab (Cancer), we look on the globe or chart for the sign ♋, and find there the preceding constellation, viz., that of the Twins (Gemini). (See fig. 41.)

As has been already stated, the ecliptic cuts the equator at an angle of $23\frac{1}{2}°$ in two opposite points distant 180°. These are the points which we call the equinoctial points, or the equinoxes: the sun at the vernal equinox, on the 21st of March, is in the constellation of the Fishes (Pisces). and in the sign of the Ram, and at the autumnal equinox, on the 23rd of September, he is in the constellation of Virgo, and in the sign of the Balance (Libra).

61. This apparent motion of the sun we must now refer to its real cause, viz., the motion of the earth.

To assist us in comprehending this motion, we again employ a round table, with a light in the centre to represent the sun. We now place the table in the centre of a circular room, round the wall of which the signs of the ecliptic are described at equal distances, and on the same level with the light on the table. In fig. 41 the inner circle represents the table, and the outer the circumference of the room. The observer's eye is supposed to be on a level with the light, and in the place indicated by the arrow (←) at 360°, where we suppose the earth to be commencing her motion on the 21st of March in the direction of the arrow (→). At this precise time the sun appears in the sign Aries. Moving along the margin of the table, which is divided into twelve equal parts, in one such part farther on, we perceive the sun in the sign of Taurus, and he appears to have described an arc of 30° in a direction precisely opposite to ours. Thus we proceed in our course round the sun, and perceive

him passing from one sign to another till he appears again in that of the Ram, and the year is completed.

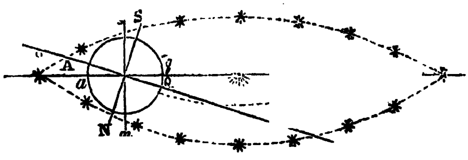


41.

Before the motion of the earth round the sun was established on certain data, the earth was believed to be in the centre of the ecliptic, *i. e.*, in the place where the sun really is, fig. 41. In fact, the phenomena are the same, if we place ourselves in the centre of the table and cause a light representing the sun to be carried round it, beginning at the lower arrow. We see the light passing through all the signs.

That the ecliptic cuts the equator at an angle of 23½°, is merely a result of the inclination of the earth's axis towards its orbit.

In fig. 42 we see the sun surrounded by an inner circle which represents the earth's orbit, and by an outer circle which is formed by the stars of the ecliptic.



42.

If the axis of the earth *n s* were perpendicular to the plane of both these circles, the ecliptic would coincide with the plane of the equinoctial *a q*. The actual position of the axis is, however, inclined towards both these circles, as N S, in which case A Q is the equator, the plane of which evidently cuts the plane of the ecliptic under the same angle which the imaginary perpendicular axis *n s* forms with the inclined axis N S.

Equation of Time.

62. The earth rotates with perfect uniformity around its own axis in 23 hours, 56 minutes, and 4 seconds. This period is called a *sidereal day*. Like the solar day it is divided into 24 equal parts, and each such part is called a *sidereal hour*. Astronomers make use of this time because they can examine it with the greatest facility and accuracy, and can, by its means, easily determine the position of a star.

On the other hand, the time which the sun requires from one transit through the meridian of a certain place to the following transit is called a *solar day*. This is about 4 minutes longer than a sidereal day, because the sun appears to have removed about 1 degree every day towards the east. It is similar to the minute-hand of a watch, which after having been directly over the hour hand must make somewhat more than one revolution to reach the hour-hand again, since the latter has, in the mean time, traversed a certain distance in the same direction.

The solar day has always been divided into 24 hours. A well-constructed and rightly-situated sun-dial always indicates the hour correctly.

The solar days, however, are not of equal duration, since, as we have seen, they depend upon the unequal motion of the earth in her elliptical orbit, which causes the apparent motion of the sun; and also because the sun does not appear to move in the plane of the equator, but in the ecliptic, which is inclined $23\frac{1}{2}°$ towards it.

But as a good clock ought to have a perfectly uniform movement, it cannot of course indicate the inequalities of solar time; hence the so-called mean solar time has been introduced. Besides the sun itself, we may imagine another sun which moves with uniform velocity in the plane of the equator, and which always passes simultaneously with the actual sun through the vernal equinox.

The imaginary sun sometimes precedes and sometimes follows the actual sun, and several times they pass simultaneously through the meridian. A watch which points always to the hour of twelve when the imaginary sun passes through the meridian indicates the mean solar time which is so termed in contradistinction to the true time indicated by the sun-dial. The difference between the mean and true solar time is called the *equation of time*. The following table shows the equation of time for the different months accurately to one minute. If it be desired to regulate a watch according to the sun-dial, we are obliged to add to or subtract from the time indicated by the dial as many minutes as are indicated by the table.

If, for example, the sun-dial, on the 26th of March, indicates 10 hours 17 minutes, the watch must indicate 10 hours 17 minutes + 6 minutes, or 10 hours 23 minutes; and also for the 7th of September, if the sun-dial indicates 8 hours 55 minutes, the watch must point to 8 hours 55 minutes — 2 minutes, or 8 hours 53 minutes.

EQUATION of TIME.

Month	Day	Min.
January	1	+ 4
	4	+ 5
	6	+ 6
	8	+ 7
	11	+ 8
	13	+ 9
	16	+10
	19	+11
	23	+12
	27	+13
February	2	+14
	13	+14½
	20	+14
	27	+13
March	4	+12
	8	+11
	12	+10
	16	+ 9
	19	+ 8
	23	+ 7
	26	+ 6
	29	+ 5
April	1	+ 4
	5	+ 3
	8	+ 2
	12	+ 1
	15	0
	20	− 1
	25	− 2
May	11	− 3
	15	− 4
	29	− 3
June	5	− 2
	10	− 1
	15	0
	20	+ 1
	24	+ 2
	29	+ 3
July	4	+ 4
	11	+ 5
	20	+ 6
August	2	+ 6
	11	+ 5
	17	+ 4
	21	+ 3
	25	+ 2
	29	+ 1
Sept.	1	0
	4	− 1
	7	− 2
	10	− 3
	13	− 4
	16	− 5
	19	− 6
	22	− 7
	25	− 8
	27	− 9
	30	−10
October	4	−11
	7	−12
	11	−13
	15	−14
	20	−15
	28	−16
Nov.	3	−16¼
	9	−16
	17	−15
	21	−14
	25	−13
	28	−12
Dec.	1	−11
	3	−10
	6	− 9
	8	− 8
	10	− 7
	12	− 6
	15	− 5
	17	− 4
	19	− 3
	21	− 2
	23	− 1
	25	0
	27	+ 1
	29	+ 2
	31	+ 3

EARTH AND MOON.

63. A relation similar to that between the sun and the earth exists also between the earth and the moon; the latter is attached to the earth by the invisible bond of attraction, and, as its satellite, accompanies it in its path round the sun.

On comparing these two bodies, the moon and the earth, we find the moon's diameter to be 2,157 miles, or 3·67 times smaller than the diameter of the earth. The surface of the earth is about 14 times larger than that of the moon, and, in solid contents, is 50 times greater. To an observer in the moon the earth must appear 3·67 times larger than the moon appears to us. The apparent diameter of the latter is 31′ 16″.

The distance of the moon from the centre of the earth is 237,840 miles, or 60 semi-diameters of the earth, an insignificant space when compared with the distance of the sun, and especially when contrasted with the distances of the fixed stars. Indeed the moon is of all the heavenly luminaries the nearest to us, and it is owing to this that she apparently surpasses in magnitude all other celestial bodies, except the sun, and that, in appearance, she is almost of dimensions equal to him.

This proximity enables us to make important observations on the body of the moon, which being magnified 500 times, or brought nearer by a powerful telescope, affords a spectacle as surprising as it is beautiful. When with the unassisted eye alone the moon is viewed, we perceive large dark parts to which fancy and tradition have often assigned a human or other appearance; the armed eye, however, represents these in a more definite manner, and we have in

general acquired tolerably well-grounded views respecting the condition of the moon's surface.

In the half-moon, while the enlightened border towards the sun is circular and smoothly rounded off, the opposite border is indented and jagged, with deep recesses and prominent points. That certain clear points in the moon are mountains there is no reasonable doubt, from the long-projecting shadows that their unenlightened sides cast behind them; as the altitude of the sun increases they shorten, and at full moon disappear. By admeasurement, it has been discovered that some of these mountains are as high or even higher than any terrestrial mountains. Annular mountains (*Ringgebirge*) are the most common form of lunar mountains: sometimes these enclose an extensive plain, sometimes a crater of great depth, having sometimes a conical elevation in its centre called the central mountain. Besides these, there are groups and chains of mountains traversing the moon in every direction; so that by far the larger portion of the lunar surface is occupied by these diversified mountain ranges. This may be discovered through a moderately good telescope.

On comparing the appearance of the lunar mountains with those of the earth, and with the idea which we entertain of the origin of terrestrial mountains, a *volcanic* origin is with good grounds ascribed to the former.

According to the most exact observations, it appears that the moon has no atmosphere similar to ours, that on its surface there are no great bodies of water like our seas and oceans, so that the existence of water is doubtful. The whole physical condition of the lunar surface must, therefore, be so different from that of our earth, that beings organized as we are could not exist there.

It would be ridiculous to waste time in refuting the assertion, that edifices and even living creatures might be seen on the moon. If we were in a condition to apply telescopes magnifying a thousand times, the moon would appear in that case no other than a place 50 miles distant appears to the naked eye; yet who can discern a house or a living creature of any sort at such a distance?

64. The lunar orbit is an ellipse having the earth in one of the foci, and its eccentricity is greater than that of the earth's orbit, that is, it varies in a greater degree from the circular figure.

Hence the moon is not always equidistant from the earth, but has its *apogee*, its *perigee*, and mean distance, similar in this respect to the relations existing between the earth and the sun (§ 53), already described. Hence its apparent magnitude is not uniform: its greater apparent diameter is 33′ 20″, and the smaller 29′ 12″, and the mean 31′ 16″, according to its distance from the earth. The celerity of the moon's motion is the greater, the more it approaches the earth.

But since the moon moves at the same time with the earth around the sun, its motion is very complicated, being that of a spiral line about the earth's orbit, the calculation and determination of which are attended with very great difficulties.

But these vanish when we first of all submit to consideration the relation of the moon to the earth, assuming the earth as the centre of the lunar orbit.

The path traversed by the moon in the heavens is certainly within the zodiacal circle, yet it does not exactly coincide with the sun's apparent course, the ecliptic, but cuts this at an angle of a little more than 5°, in two opposite

points, which are called the moon's *nodes*, or nodes of the lunar orbit. The one half is therefore north, and the other half south of the ecliptic.

If the position of the moon, in respect to any known star, be observed on one evening and repeated the next, the moon will be found to have moved a little more than 13° from west to east from that star. As the whole circle of her orbit is 360°, accurate calculation has proved that this space is traversed by the moon in 27 days 7 hours 43′ 12″, after which time she has returned to the same star. This time is called the moon's *periodic* time or periodicity.

During the moon's course round the earth in the above-stated period, she turns once on her own axis, which is almost perpendicular to the ecliptic, so that the lunar equator nearly coincides with it, and, consequently, in the moon the same phenomena relative to the sun will be observable which the earth would have presented if, as in § 56, the earth's axis were perpendicular to the plane of the ecliptic.

One consequence of this protracted period of lunar rotation is, that the one-half of the moon will have the sun's rays for nearly 15 days, and the other side during this period would be in darkness, were it not for the reflected light she receives from the earth.

From our earth only one side of the moon, or one-half of the lunar surface, is ever visible, *i. e.*, the moon always presents the same face to the earth. This is occasioned by the coincidence of the period wherein the moon revolves round the earth and that in which she moves round her own axis. Her revolution and rotation are accomplished in the same period. This fact may be proved experimentally. Let us imagine a candle placed upon a round table; if we now walk round the table, keeping the face always turned towards the light, we do not merely pass round the table, but, in the mean time, turn round our own axis.

SUN, EARTH, AND MOON.

Phases of the Moon.

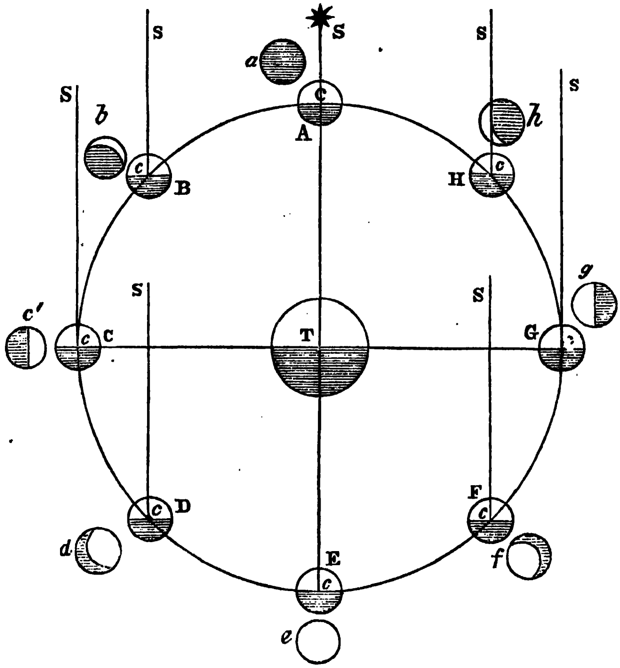
65. No other heavenly body shows such remarkable changes in its aspect as the moon. This is so striking, that the phrase, "changeable as the moon," is proverbial.

For an explanation of the different aspects, or *phases of the moom*, we must have recourse to the sun, for these are the result of the changes of the mutual positions of the sun, the earth, and the moon.

We have first to remark that, on account of the great distance of the earth and the moon from the sun, and the great magnitude of the last, all the rays of light that proceed from the sun fall in a parallel direction upon the earth and moon, and it is indifferent at what portion of their orbits they receive these rays.

Therefore let T, fig. 43, represent the earth, and c c. . . .the moon in the various positions she assumes in her orbit, and S S. . . .the rays of light proceeding in a parallel direction from the distant sun. It is evident that the surfaces both of the earth and moon opposite to the sun will be completely enlightened, and to an eye placed in the sun these two bodies would present the appearance of constantly enlightened, perfect discs. The reverse side, viz., that which is not opposite to the sun, is naturally dark.

Suppose the sun, the moon, and the earth to be in one straight line, in the order of sun, moon, and earth (S A T, fig. 43), this position is called *conjunction ;*



45.

and when the earth is between the sun and the moon, it is called *opposition*, as S T E. The two positions C and G are called the moon's *quadratures.* From the earth, only that half of the lunar surface which is turned towards us is visible, that is, that part of our diagram which is cut by the circle representing the orbit of the moon. Whilst, therefore, A B C D E F G H represent the moon as she would appear if viewed from the sun, the figures in juxtaposition, viz., *a b c′ d e f g h*, represent the phases of the moon as they actually appear to an eye on the earth observing them in these several positions.

In the lunar conjunction at A the unenlightened disc of the moon is turned towards the earth, and we have then *new moon* as it is termed. At this period the moon is scarcely visible, but in some states of the atmosphere she appears as a pale ash-gray body, reflecting the little light borrowed from the earth. After a few days she appears to us at B , as a shining crescent *b*, the points of which are turned from the sun. In the quadrature C she increases to the *first quarter c′*, where she presents her semi-lunar shape. When she reaches the opposite point of her orbit, and is in opposition, we have what is called *full moon.* By a similar gradual decrease she returns to that part of her orbit, where she is again in conjunction.

The following simple operation will afford a satisfactory view of the lunar phases. In the centre of a table, place a rather large globe to represent the earth, about which, a smaller globe representing the moon may be carried, preserving an equal distance from the centre. At a suitable distance from both, place a light to represent the sun, and at the same height as the two globes. In this experiment it is usual to colour the lunar globe white, that the exact shadow line may be sharply defined. If from the large globe we now look at the lunar globe, during its revolution, we shall obtain a very accurate view of the different phases of the moon.

66. Since the moon daily describes an arc of 13° in the heavens, from west to east, it is certain that her rising or appearance above the horizon will be later every successive night; and in this respect she differs from the fixed stars, which preserve to a minute the exact period of rising and setting. As the rising or setting of the moon can be exactly calculated, and is besides a matter of considerable importance, both this, as well as her different phases, are given in the Almanac; but with greater fulness in the Nautical Almanac.

TIDES.

67. As the attraction between the different portions of matter is always mutual, the moon is not only attracted by the earth, but the latter is also attracted by the moon. Lunar attraction is most powerfully and sensibly felt on those portions of the earth's surface that are nearest to the moon, which is the case when the moon passes through the meridian of these places. Attraction is strongest on the equator—because the moon is always nearly perpendicular to this part of the surface of the earth.

On the continental parts of the earth, lunar attraction exerts scarcely any perceptible influence; whilst, on the contrary, the waters of the ocean which cover the greater portion of the earth's surface, by their mobility, more easily follow the attracting influence, and are elevated in the direction of the meridian where the moon is present.

This elevation of the waters of the seas and oceans, at stated periods, is called the *flow*, or flux of the *tide*, and, as has been shown, is always greatest at the equator, and gradually decreases with the increase of latitude. For example, at St. Malo it amounts to 50 feet, while on the northern part of the Norwegian coast, it is scarcely perceptible.

Even the centre of the earth is susceptible of attraction in this direction, and in some degree yields to it; hence the waters on the opposite side of the meridian are elevated, because in consequence of their inertia they are not in a condition instantly to obey the motion of the attracted earth. Thus the flood-tide forms a belt or ring, encompassing the whole globe, passing through the poles, attaining its greatest elevation at the equator, and gradually diminishing towards both poles, where it altogether disappears. The direction of the tidal wave is from east to west, regulated by the moon's gradual motion to the meridians of the different places.

Consequently at any one place, during the space of 24 hours, there are two tides, which are 12 hours apart, and at the periods when this phenomenon occurs in our locality, the sea is also elevated in the locality of our antipodes.

But, again, if the oceanic wave is elevated at the same period in opposite parts of the earth, and, by its cumulative process, occasions, what is termed,

high water at these opposite points, at the intermediate points the water must naturally in the same measure be lower, and occasion the *ebb* or reflux tide; and this reflux must be greatest at those points equally distant from the points of high water or flood-tide. All places lying under the same meridian have ebb or reflux tide at the same time; and this tidal depression forms a concave circle which, in the poles, cuts the circle of the high tide at right angles.

On the sea-shore we perceive, during six hours, the waters flowing towards the land, accumulating on the sea-beach, or covering the flat sands, flowing up the estuaries of tidal rivers, or dashing themselves to foam and spray on the lofty banks or steep rocky barriers of the ocean: when they have reached their maximum height, they appear quiescent for the space of a quarter of an hour; they then flow back to the sea during six hours longer, when they recommence their fresh reiterated attacks on the firm barriers of the stable ground.

There does not exist a more sublime and fearfully awful spectacle, than the sea affords when agitated by the combined influence of both tide and storm.

The howling of the tempest, the roar of mighty waves, the rushing sound of the broken waters, vainly struggling to pass their appointed bounds, form a scene difficult to be imagined, and impossible to be described.

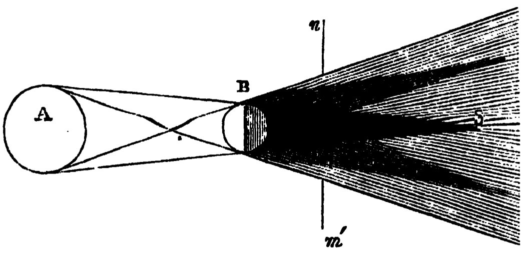
As the moon appears on the meridian, the following day, about 50 minutes later than on the previous day, and as the time of high water at every individual place corresponds with the lunar motions, the phenomena of ebb and flow, or of high and low water, can be ascertained for every haven—an object of the utmost value in navigation.

In general, however, the tides do not occur so simply as has been above described. Besides local peculiarities, such as the configuration and position of the shore, occasional causes as winds, &c., disturb the regular progress of the tide. And besides these, the sun has an important effect on the flow and ebb, according to his relative position to the earth and moon.

If the sun and moon be in conjunction (see fig. 43), by their combined influence the tides are higher, but if they be in opposition, they counteract each other, and the tides are lower. The sun's influence is least, when the moon is in her quadratures.

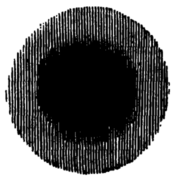
Eclipses.

68. Eclipses of the heavenly bodies are merely the shadows of certain opaque bodies thrown upon others coming within the verge of their darkened sides. If the luminous body A, fig. 44, be of larger dimensions than the dark body B,



44.

there originate, in consequence of the rectilinear propagation of light, two sorts of shadows. The *umbra* is that sort of shadow in which no part of the luminous body is perceptible; it forms a cone, the apex of which is behind the dark body. As soon as the eye is placed on the umbra, it can perceive no part of the source of light A, which appears to be eclipsed. On the other hand, the *penumbra* originates in that locality where only a portion of the light proceeding from a luminous object can fall; hence an eye in the *penumbra* would see a part, but not the whole of the illuminating body. This shadow, also, forms a cone, which, if extended, the apex will fall before the opaque body. If we receive the shadows so projected at *m n*, for example, on a white sheet, we have in the centre a dark circle, which is the umbra, surrounded by the penumbra, which gradually decreases in intensity towards the exterior (see fig. 45). The farther we hold the sheet from the body producing the shadow, the umbra decreases, and the penumbra is enlarged.



45.

Lunar Eclipse.

69. Let A, fig. 44, be the sun, and B the earth, the length of the umbra of the latter will exceed 108 diameters of the earth. Since the moon is only about 30 terrestrial diameters distant from the earth, and as the diameter of the earth's shadow, at this distance, is nearly three times as large as the apparent diameter of the moon, it follows that when the latter enters this shadow, she must be totally eclipsed.

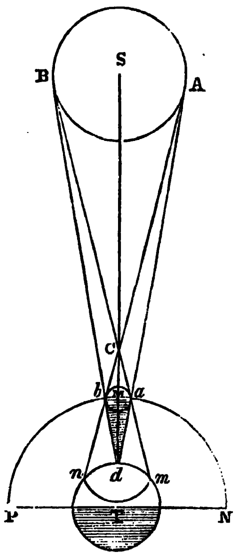
If the moon's orbit was coincident with the ecliptic, or if both moon and earth moved round the sun in the same plane, there would be an eclipse at every conjunction, and at every opposition, (see § 65), *i. e.*, a solar eclipse would happen at every new moon, and a lunar eclipse at every full moon. But we have seen that the lunar orbit cuts the ecliptic only in two points (Nodes, § 64), ; consequently an eclipse of the moon is possible only when, at the time of opposition, the moon is in one of her nodes, or in close proximity to it, which can only occur 29 times in the space of 18 years.

70. A lunar eclipse begins on the eastern margin of the moon, and is either *total*, when her whole disc enters the umbra, or *partial*, when only part of her disc is in the shadow. A total eclipse may last for two hours.

Eclipses of the moon are visible at all points of the nocturnal hemisphere of the earth, if the moon be above their horizon, and the eclipse will be of equal duration and equal magnitude. If, however, the places of observation lie at a considerable distance east and west of each other, the commencement and termination of the eclipse will be perceived at different times; and hereby we have the means of determining the longitude, *i. e.*, the distance of the observer from the first meridian (see § 25). The greater the distance between two places, the greater will be the difference of time at which an eclipse will begin or end at the two places. Suppose for the one place the eclipse begins at 10 P.M., and at a place farther to the west at 11 P.M., we know that the difference of the longitude of the two places is 15°. The circular outline of the earth's shadow on the moon, is a notable proof of the sphericity of the earth.

SOLAR ECLIPSE.

71. When the moon and the sun are in conjunction, the moon's place may be represented by M. fig. 46; between the earth T, and the sun, S. If this conjunction occur when the moon is in one of her nodes, or within 16° of it, the shadow of the moon will fall upon the earth, and the sun will be eclipsed. This can only happen 41 times in 18 years; and it will presently be shown that, at any one place, an eclipse of the sun is three times less frequent than an eclipse of the moon.



46.

The lunar umbra extends from the moon a space about equal to her distance from the earth, and hence only a small portion *d* of the earth's surface enters the lunar umbra. To the inhabitants of this part of the earth the sun will be totally eclipsed, and the eclipse will be annular if only the margin of the sun's disc remain uneclipsed by the lunar shadow. This is only possible when the moon is in her apogee, or greatest distance from the earth, where her apparent diameter is less than that of the sun, which it cannot in general exceed more than 1′ 38″. Hence the duration of a total eclipse cannot be more than 3¼ minutes.

On the contrary, the penumbra of the moon is diffused over a much larger portion, *n m*, of the surface of the earth, since its section is five-ninths of the earth's diameter. The inhabitants of this portion of the earth do not receive light from all parts of the sun, consequently a *part* of this luminary is invisible to them, and the eclipse is said to be *partial*.

Solar eclipses commence on the western margin of the sun, and advance to the eastern. On account of the proximity of the moon to us, an eclipse of the sun is, in all places above the horizon of which the sun appears, visible neither at the same time, nor is it of equal duration, nor of equal extent: in some parts it may not be visible at all. In favourable situations, the diameter of the umbra, where it reaches the earth, amounts to about 167 miles, and in this small strip of the earth's surface only can the sun appear totally eclipsed.

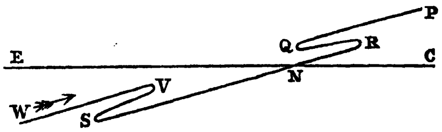
PLANETS.

72. It has been already stated (§ 45) that, on an attentive observation of the heavenly bodies, certain stars are observed which obviously change their positions in relation to the fixed stars, and which have therefore been called planets or wandering stars.

If examined through a telescope, they appear considerably magnified, with commensurable discs illuminated by the sun, whose light they receive and reflect. In these respects they differ essentially from the fixed stars, which even under the greatest magnifying power appear only as small luminous points, and are considered to be self-illuminated bodies, or suns, at enormous distances.

Compared with the fixed stars, the planets are at moderate distances, and insignificant in number, but in other respects they are invested with a remarkable interest.

The planetary motions are confined to the portion of the heavens called the Zodiac (see § 60). But how essentially different are their orbits from those of the sun and moon! Whilst these preserve a uniformity of motion, describing equal arcs in definite spaces of time, advancing from west to east, from one constellation to another, till they have completed a whole circuit of the heavens, we perceive that the case is widely different with the planets. Sometimes they advance rapidly, then relax their apparent speed, then stand for some days perfectly still, and then reverse their motions, and again describe an irregular line, somewhat like the representation in fig. 47. The planet's course, W V, in the direction of the sun's path, is called its *direct* motion, and its reverse motion, V S, is called *retrograde*, and between these two kinds of motion the planet is always for a time stationary. We also perceive that half of a planet's course is on the north and half on the south side of the ecliptic, E C; consequently their orbits cut the ecliptic at two opposite points, termed *nodes*, similarly to the moon's.



47.

Before we arrived at the correct knowledge of the planetary courses, and the relation of these bodies to the sun, nothing was more difficult than the *explanation* of their peculiar motions. All the attempts of the earlier erroneous systems of astronomy were wrecked by the planets, and thereby proved at once their inaccuracy or insufficiency.

73. The sun is not only the centre of attraction for our earth, which describes its elliptic course around him, but also for a great number of other heavenly bodies, the first of which are the planets, among which the earth itself must be classed.

We know at the present day 22 planets, and from recent discoveries we have ground for the assumption that more planets are discoverable.

The planets present essential differences in magnitude, distance from the sun, celerity of movement, and in physical characters; they all agree in form, opaqueness, and in the ellipticity of their orbits around the sun, which lie almost in one plane. A rotatory motion on their axes has been observed in so many, that it is a fair assumption that they all possess this property.

74. The planets may be systematically represented, relatively to each other and to the sun, by drawing them of proportionate magnitude, and at proportionate distances, on a table, or even on a sheet of paper. The sun is, of course to be assumed as the fixed and common centre of attraction, around which the orbits of the planets may be described either as circular or elliptical.

A tolerably satisfactory diagram of the relative distances of the planetary bodies may be constructed by assuming the mean distances of these bodies from the sun, as the radii of a succession of concentric circles, each one representing the orbit of a single planet. In order to describe their ellipticity, the larger diameter and eccentricity (§ 13) must be given.

The planets situated nearer than the earth to the sun, of which there are

only two, Mercury and Venus, we distinguish by the title *inferior* planets; those moving in orbits, lying on the outside of the earth's orbit, we call *superior* planets, which include all the other planetary bodies.

By the term *ancient* planets, we understand those that have been known since the most remote ages, viz., Mercury, Venus, the Earth, Mars, Jupiter, and Saturn; whilst the rest, discovered since the invention of telescopes, are styled *modern* planets.

The following tables comprehend the most important relations of the planets:—

I.

Planets.	Signs.	Known since	Discovered by	Diameter.		Solid Contents.	
				English Miles.	Greatest apparent.*	Millions of Cubic Miles.	Earth = 1.
1. Mercury -	☿	Antiquity	-	3,123	13″	10,195	$\frac{1}{17}$
2. Venus -	♀	,,	-	7,702	64″	223,521	$\frac{10}{11}$
3. Earth -	♁	,,	-	7,916	-	260,775	1
4. Mars - -	♂	,,	-	4,398	23″	48,723	$\frac{1}{7}$
5. Flora -	[illegible]	1847	Hind - -	-	-	- -	-
6. Victoria -	[illegible]	1850	,,	-	-	- -	-
7. Vesta -	⚶	1807	Olbers -	238	0″·5	98	$\frac{1}{17638}$
8. Iris - -	[illegible]	1847	Hind - -	-	-	- -	-
9. Metis -	[illegible]	1848	Graham -	-	-	- -	-
10. Hebe -	[illegible]	1847	Hencke -	-	-	- -	-
11. Parthenope	[illegible]	1850	DeGasparis	-	-	- -	-
12. Astrea -	[illegible]	1845	Hencke -	-	-	- -	-
13. Egeria -	-	1850	De Gasparis	-	-	- -	-
14. Juno - -	⚵	1804	Harding -	1,425	0″·4	1,372	$\frac{1}{9842}$
15. Ceres -	⚳	1801	Piazzi -	1,024	-	20,783	-
16. Pallas -	⚴	1802	Olbers -	2,099	4″·2	- -	$\frac{1}{1661}$
17. Hygeia -	[illegible]	1849	De Gasparis	-	-	- -	-
18. Irene - -	-	1851	Hind - -	-	-	- -	-
19. Jupiter -	♃	Antiquity	-	91,522	49″·2	343,125,828	1,491
20. Saturn -	♄	,,	-	76,068	20″·3	245,089,877	772
21. Uranus -	♅	1781	Herschel -	35,112	4″·3	19,727,774	87
22. Neptune -	♆	1846	Adams and Leverrier	-	2″·6	- -	77
Sun - -	☉	-	-	882,270	32′·34″	399,839,629,687	1,415,225
Moon -	☽	-	-	2,160	31′·16″	5,274	$\frac{1}{50}$

* The apparent diameter is expressed by the number of seconds contained in the angle under which the planet is seen from the earth at its shortest distance.
The smaller and recently-discovered planets are usually called Asteroids. For these, recent admeasurements prove that the above-assigned diameters are too large.

II.

Planets.	Mean Distance from the Sun, or Half the greater Axis of their Orbits.		Eccentricity in parts of its Semi-major Axis.	Time of Rotation round their Axes.	Time of Revolution round their Orbits.	Celerity of Orbitual Motion, or space passed over in a Second.
	Miles.	Earth's Distances.				
	1	2	3	4	5	6
				Hrs. min.	Days.	Feet.
1. Mercury - -	36,000,000	0·3	0·205	24 0	88	162,611
2. Venus - -	68,000,000	0·7	0·006	23 21	225	118,960
3. Earth - - -	93,000,000	1·0	0·016	23 56	365	101,173
4. Mars - - -	142,000,000	1·5	0·093	24 39	687	81,963
5. Flora - - -	209,846,610	2·2	0·156	-	1,194	-
6. Victoria - -	- -	-	-	-	1,303	-
7. Vesta - - -	225,000,000	2·3	0·093	-	1,335	65,813
8. Iris - - -	223,034,070	2·3	0·207	-	1,344	-
9. Metis - - -	- -	-	-	-	1,346	-
10. Hebe - - -	223,771,830	2·3	0·182	-	1,380	-
11. Parthenope -	- -	-	-	-	1,401	-
12. Astrea - -	245,305,200	2·5	0·188	-	1,511	-
13. Egeria - -	- -	-	-	-	1,478	-
14. Juno - - -	253,000,000	2·6	0·255	-	1,591	61,909
15. Ceres - - -	263,000,000	2·7	0·078	-	1,681	60,821
16. Pallas - - -	265,000,000	2·7	0·245	-	1,682	60,820
17. Hygeia - -	- -	-	-	-	2,042	-
18. Irene - - -	- -	-	-	-	-	-
19. Jupiter - -	485,000,000	5·2	0·048	9 56	4,333	44,362
20. Saturn - -	890,000,000	9·2	0·056	10 16	10,758	32,757
21. Uranus - -	1,800,000,000	19·2	0·045	7 5	30,687	23,093
22. Neptune - -	3,446,722,500	36·1	0·008	-	-	-

75. The two inferior planets, *Mercury* and *Venus*, have phenomena in some respects similar to those of the moon. As they move between the orbit of the earth and the sun, they enter with these bodies, at certain times, into a twofold conjunction, viz., in an *inferior conjunction*, when the planet is between the sun and the earth, and in a *superior* when it is beyond the sun, and in the same straight line with the earth. During the superior conjunction, which frequently occurs in the planet Mercury, caused by the rapidity of its orbitual motion, we occasionally obtain a view of this body, as a dark, round speck passing over the sun's disc. This passage over the sun is called the *transit* of Mercury, and it affords a convincing proof that the planets derive their light from the sun.

In certain positions towards the sun, when viewed through a telescope, this planet clearly exhibits certain alterations of form, which are called phases. Venus, at certain periods, and especially in the morning, after being for some time invisible, appears as a bright sickle. Venus is in general readily recognised by her brilliancy and considerable apparent magnitude, as well as by her proximity to the sun. In consequence of this proximity she is visible always at the time of sunrise and sunset, and hence she has received the name of *morning* and *evening star* (Lucifer and Hesperus). An atmosphere and lofty mountains have been observed in this planet, and a rotatory motion about her axis, which lies nearly in the plane of her orbit.

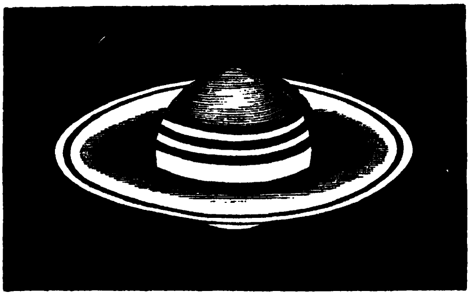
76. The superior planets describe their paths around the sun and earth, and, consequently, they enter into conjunction, opposition, and quadrature to these bodies (see § 65). The nearest to us, viz., the planet *Mars*, is distinguished by a remarkable dusky-red light (colour), which has been ascribed to a very high and dense atmosphere.

Mars is likewise remarkable for his oblateness, which is produced by the motion round his axis, as well as for the bright spots observed in the vicinity of his poles, forming the so-called *snow-zones*, which decrease when the pole, where this phenomenon is observed, is turned to the sun; similar to the phenomena observed on the polar regions of the earth.

Jupiter is distinguished both by his splendour and by his magnitude, being the largest of the planets, as has been shown in Table I., as well as by different belts or zones which are parallel with his equator. An atmosphere has been attributed to this mighty planet. The velocity of its rotatory motion is enormous, being accomplished round its almost perpendicular axis in the space of 10 hours, or at the rate of 28,000 miles an hour. Its oblate figure is (Com. Phys., § 56) a consequence of the celerity of its rotation; its diameter at the poles compared with that of the equator is as 13 : 14.

This stupendous planet is accompanied by four *moons* or *satellites* which present similar appearances to the inhabitants of Jupiter, as the moon to us. Although these moons are considerably larger than ours, they are only visible by telescopic aid. They are remarkable as affording data for calculating the velocity of light. As these moons revolve around Jupiter, they enter from time to time in the umbra of this planet, and are eclipsed. After the moment of immergence and emergence had been exactly calculated, it was found that at the time of conjunction, when the earth and Jupiter are 193,662,000 miles distant, the eclipses of Jupiter's satellites appear considerably *later* than when the same phenomenon takes place at the time of their opposition, when the two planets are nearer to each other. The last rays of a satellite, disappearing in the shadow, reach us some time after the body is actually eclipsed, consequently the light requires a certain time to travel to the earth, and this time amounts to a second for 195,000 miles.

77. The planet *Saturn* is peculiar for an annular disc which surrounds it in the neighbourhood of its equator, and rotates freely round the planet. It is only visible to the aided eye in certain positions, viz., when Saturn is in the signs of Aries and Cancer (fig. 48). By attentive observation, this disc is discovered to consist of three rings, which like the mass of the planet are solid, and cast a shadow, clearly visible on the surface of the planet. This ring may be represented as consisting of a large number of small satellites arranged in a contiguous annular form, and performing their revolutions round the planet in the same time.



48.

Besides the ring, Saturn is accompanied by seven moons revolving round him at greater distances, and are likewise only visible by the aid of a powerful telescope.

78. Till lately *Uranus* was the most remote planet of our system; it is scarcely visible to the naked eye, and was unknown to the ancients. It is attended by six satellites, of which only two have been accurately observed.

The recently-discovered planets we shall notice below.

Planetary System.

79. The renowned Ptolemy who lived about the middle of the 2nd century of our era, and who belonged to the celebrated Alexandrian school, made the first attempt to classify and explain the phenomena of the heavenly bodies, by laws founded on observation. Antiquity solved all such questions as might originate in an enlightened curiosity on mythic principles, poetical and fanciful, sometimes beautiful, but very illogical and unscientific.

According to the Ptolemaic system, the earth is in the centre of 11 hollow spheres, arranged concentrically within each other, and consequently placed at different distances, and of correspondingly increased magnitudes. In each one of these hollow spheres, which were necessarily supposed to be of the purest crystal, the heavenly bodies were arranged in the following order, viz., the Moon, Mercury, Venus, Sun, Mars, Jupiter, and Saturn: in the eighth crystalline sphere the fixed stars were supposed to be placed. The last three were reserved for the explanation of certain other phenomena.

It is evident that this system is decidedly contradicted by many phenomena, and as this was then manifest, the *Egyptian* planetary system was proposed as an improvement. Mercury and Venus were made satellites of the Sun, who still continued his journey around the earth. Still many remarkable phenomena were unexplained, and especially the peculiar movements of the planets described in § 72. This portion of the science appeared so enigmatical, that its votaries were compelled to take refuge in many fantastical assumptions.

The true system of the universe was undiscovered till near the middle of the 16th century, when Copernicus, who was born in 1473, and died in 1543, comprehended this vast problem, and originated the happy idea of the true solar system, an idea which he cherished during the whole course of his life, and laboured to establish on the sure basis of reckoning and observation. He maintained that the sun was the centre of the system, that the planets moved around the sun in circular orbits, and he farther taught that the daily motion of the heavenly bodies was only apparent, and caused by the rotation of our earth.

The persecution of Galileo, the eminent Italian astronomer, is a proof that the spreading of such new cosmical doctrines was not unattended with danger to their supporters and abettors. This great man, who adopted and farther developed the Copernican system, was compelled to recant his real opinions, and to profess his belief in the immobility of the earth, because the whole system stood in verbal opposition to some passages in the Holy Scriptures.

80. There were still several inexplicable phenomena, such as the change of planetary velocity, at certain periods, and the evident alterations of their appa-

rent magnitudes, both appearances inconsistent with the assumption of their moving in perfectly circular orbits.

At this period appeared the great Keppler, born at Weil, in Wurtemberg, 1571, who availed himself of all the hitherto ascertained facts connected with Astronomy, and especially of the observations of his distinguished contemporary Tycho Brahe; by these means Keppler developed the ever-memorable laws, which have rendered his merits unsurpassed and his name immortal. This illustrious man had to maintain a fearful struggle with the common domestic miseries of life, and with the outward calamities of war, was driven from one place to another, with no earthly possession, but his own elevated conceptions.

81. Keppler's laws are the following:—

1. The orbits of the planets are *ellipses*, which have a common focus wherein the sun is placed.
2. Equal areas are described by the planets in equal times; that is, the radii vectores drawn from the focii (§ 13) to the planet, will always stretch over an equal space in the same duration of time in which the planet itself moves, it being indifferent what portion of its orbit the planet may in the meanwhile traverse.
3. The squares of the times of revolution of any two planets are to each other in the same proportion as the cubes of their mean distances from the sun.

The world-renowned Newton, placed the key-stone upon the noble edifice founded by his great predecessor. By the discovery of the law of gravitation, he completed the theoretic view of the planetary system. He demonstrated that the cause of all the motions of the heavenly bodies originates in their mutual attraction towards each other; and also that this attractive power increases in proportion to the masses of the bodies attracted, and diminishes the farther the attracting bodies are distant from each other. (Physics, § 24.)

The Newtonian laws explain how all the planets, whose united magnitudes are not equal to that of the sun, are bound to the latter by the invisible bond of attraction, and how the satellites, as our moon, with those of Jupiter and Saturn, are connected with their primaries.

82. By the establishment of these laws, astronomers were in a condition to supply many deficiencies, and to correct many errors which still existed in the science: every discovery, and every new and careful observation, served to confirm the truth of these principles.

The extensive space between the orbits of Mars and Jupiter led to the idea, that an unknown planet must exist between them; the consequence was that four small planets, viz., *Pallas*, *Juno*, *Ceres*, and *Vesta*, were discovered, and they are supposed to be fragments of a greater planet. Concerning the newly-discovered asteroids we have not yet obtained very satisfactory accounts.

There is no doubt that the planets have a mutual attraction for each other, which in certain parts of their orbits, where they approach, is sensibly felt. The irregularities apparent in the motion of certain planets have been referred to this cause; they have been named *disturbances* or perturbations, and have been in some cases exactly calculated.

From inexplicable perturbations of the planet Uranus, it was conjectured

that another planet must be in existence, and its place was even determined by calculation: thus the recently-discovered planet Neptune, which in consequence of the feebleness of its light would probably still have remained a long time unobserved, was shown to exist.

COMETS.

83. On the nocturnal heavens, from time to time, there appear luminous bodies consisting of a more brilliant star-like portion, called the *head*, which is commonly followed on the side turned from the sun by a luminous *tail*, which frequently measures millions of miles in length.

These bodies are called *comets*, and were long deemed supernatural prognostications of great events, the harbingers, too often, of terrible calamities. It is not long since the appearance of a comet was considered a cause for general alarm.

But since the nature of these irregular visitants of our skies has been investigated by astronomers, and the periodicity of some ascertained, they have ceased to be objects of terror and superstitious dread.

84. Comets are material bodies deriving their light from the sun. Their substance is of such extraordinary tenuity, that even through their nucleus the light of distant fixed stars is plainly visible. They are certainly attracted by the sun, as their motions are accelerated and their brightness increased when nearest to this luminary.

Like the planets they are subject to great irregularities in their orbits, only in a much higher degree: and they also differ from the planets in not being limited to the plane of the ecliptic, but moving in all imaginable directions, sometimes approaching so near the sun as to be absorbed in his splendour, and on their reappearance receding from the sun till they are gradually lost in the immensity of space. Hence a comet is visible only for a few days, or weeks, or months; they are never seen for longer periods.

By very accurate observation it has been ascertained that their orbits like those of the planets are elliptical, but of greater eccentricity, so great, indeed, that their periodicity is of very long duration; and some of the most remarkable and beautiful comets, as those of 1680 and of 1811, are expected to return in from 1,500 to 8,000 years.

Some, on the other hand, reappear after shorter intervals, as those named after Halley, Enke, and Biela, which have been accurately calculated by these astronomers. The first has been determined to complete its revolution in from 75 to 76 years, the second in three years and 115 days, and the last in 6 years and 270 days, and they have been several times observed after these intervals.

Hitherto about 500 comets have been seen, of which number not probably more than 150 have been accurately observed. According to astronomical observations, the greater part of them appear to describe orbits which are neither circular nor elliptic, but *parabolic* (§ 14), and, consequently, their return is impossible, being lost in infinite space, and they are no longer to be considered as constituting a part of our solar system. It has been, however, conjectured that the number of comets belonging to our system may amount to about a million; and since they present themselves in all directions, we may assume the realm of the sun to be not a circular plane, in the centre of which is placed the

sun, and in whose circumference the planets move, but we must imagine the occupied space of our solar system to be of a globular form. If it be desired to convey an idea of the solar system by a model, this may be easily accomplished by means of a great number of hoops of different diameters, inclined to each other in all directions around a common centre; the diameter of the exterior being not less than 400 diameters of the earth's orbit, therefore upwards of 73,776 millions of miles.

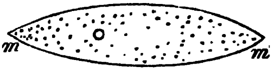
SYSTEM OF THE UNIVERSE.

85. After it had been satisfactorily determined that the sun has a rotatory movement about his axis, the conjecture was entertained that this body has also a progressive motion at the same time. We have indeed satisfactory accounts of observations confirmatory of this fact, viz., that the sun moves towards a point in the firmament which is situated in the constellation of *Hercules*. His real path or orbit is, however, of such exceedingly enormous extent that the progress of the sun cannot be ascertained till after a lapse of many years, and especially as all the bodies belonging to the solar system necessarily accompany him in this progress.

It may at all events be admitted, that there is a point in the heavens about which our entire solar system revolves, in the same manner as Jupiter and his satellites move round the sun.

More extensive observations of the heavenly bodies have confirmed the conviction, that the fixed stars constitute the centres of innumerable systems, which are in part like that of our sun, and in part composed only of two stars which at a short distance from each other, revolve round their common centre. These are named binary or *double stars*, and the number hitherto observed amounts to 4,000.

According to Herschel,* the sun is a portion of a system of a higher order, which may be represented as of a lens form, fig. 49. Here the position of our system is indicated by the little circle 0. It is evident that the heavens will present to our view fewer stars when we look upwards or downwards, than when we look in the direction $m\,m'$. In the latter case we have a view through layers of stars placed behind each other, and forming a thickly studded zone around us which we have in § 46 described as the Milky Way. It must, however, be admitted that the above-mentioned view regarding the arrangement of our solar system is by no means unquestioned.



49.

86. But if we consider the nebulous specks that are dispersed among the constellations, many of which by means of very powerful telescopes have been

* Herschel (born in 1738, died in 1822) came to London in 1759, as a musical composer and professor. He subsequently devoted himself to the study of astronomy, and engaged in the construction of telescopes, with the view of procuring funds for the erection of a larger instrument than had hitherto been employed. He was so successful, that finally he acquired the means of possessing one of 40 feet focus, viz., the gigantic telescope which surpassed in power all instruments previously constructed. Wherever Herschel turned his instrument new celestial wonders, not hitherto even surmised, disclosed themselves to his admiring eyes. He has the honour of being the discoverer of the world of fixed stars. The telescope is no longer used, and has been converted by his distinguished son, Sir J. Herschel, into a monument in memory of his illustrious parent.

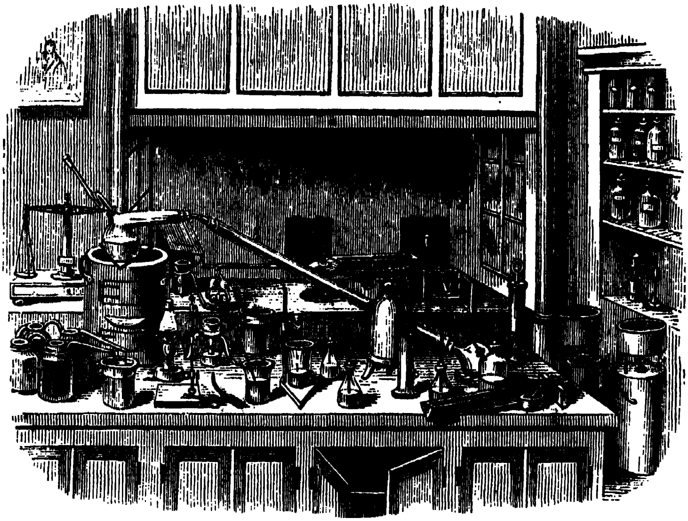
resolved into groups of stars, while others cannot be so identified on account of their vast distances, ought we not to conclude that these very remote and indiscernible bodies form the Milky Ways of other stellar systems?

When we consider that the nearest of the fixed stars is, at the very least, 200,000 times the radius of the earth's orbit distant from us, and that three years would elapse during the passage of light from that body to our globe, it may be assumed that a period of 25,000 years would be requisite to bring to our eyes the light from one of the most remote nebulous spots, and that consequently the distance of this remote object must be 152,163 billions of miles.

Thus we have from the little beacon of our earth, on which we have been placed by an Almighty Hand, taken a comprehensive survey of the solar system; we have also seen that this forms only a part of an infinitely higher order, which last may only be a small part of the infinite whole. Here we find ourselves beyond the bounds of the comprehensible, and are aware that imagination herself is lost in these wonderfully-sublime speculations.

The majesty and omnipotence of the Most High are displayed to our wondering gaze and to our bewildered minds, and we are ready to exclaim with the prophet: "*Lift up your eyes on high, and behold who hath created these things.*"

[Sir Isaac Newton.]



CHEMISTRY.

1. CHEMISTRY is the science of those phenomena which are attended by an essential *change* of the objects in which the phenomena are observed, or in those which serve for their production.

When a piece of wood or a fragment of coal is burned, or a bar of iron rusted, these objects, in fact, suffer an essential change, and a series of phenomena must be exhibited in order to restore these various bodies to their original condition.

An object changed by chemical action has naturally acquired new properties, otherwise we could not say that it is changed at all. Hence chemical phenomena are characterised by this important distinction, namely, that their results are always the production or appearance of a body endowed with new qualities. The rust observed on the iron, which is the result of chemical action, is essentially very different from the iron itself.

But we shall be in a better position to ascertain the changes a body undergoes by acquiring a precise knowledge of the properties it possessed before it suffered the chemical change. Hence the object of chemistry is to ascertain, first, the essential nature of bodies, then the changes which they undergo, and,

finally, the characters of bodies endowed with other properties, the results of this change.

2. We have been taught by the science of Physics (§ 11) that every body is assumed to be composed of an agglomeration of exceedingly minute atoms. If, now, we examine different bodies, we find that the atoms or molecules which constitute their mass are in most cases of *dissimilar* qualities. There are two processes whereby we are enabled to prove this. The preparation of the beautiful crimson colour known under the name of *cinnabar*, or vermilion, is conducted in manufactories in the following manner: 16 parts by weight of sulphur are fused, and then 100 parts of mercury are gradually added, when a black mass is produced. This is placed in a covered jar, and exposed for a long time to a high temperature. On breaking the jar, when it is cold, we find at the upper part of it a red mass which, when finely pulverized, forms the vermilion of commerce. In carefully-conducted and successful operations we obtain an amount of vermilion nearly equal in weight to that of the sulphur and mercury employed. Hence we may justly assume that in the vermilion there is only sulphur and mercury present. If we mix 116 parts by weight of vermilion with 28 parts of iron filings, and heat it in a retort, we obtain in the receiver nearly 100 parts by weight of metallic mercury (see Phys., § 129). In the retort remains a black mass amounting to 44 parts by weight, and which is called *sulphide of iron*. In addition to the 28 parts of iron which have been added, it contains the 16 parts of sulphur which had previously formed with the mercury the vermilion.

These two simple experiments teach us that in the minutest particles of vermilion two different elements are present, namely, mercury and sulphur, and although they cannot be distinguished by the best microscope, we can easily prove the fact by the above-mentioned process. In the following pages many other instances of chemical affinities will be adduced.

There are, therefore, bodies whose minutest constituent particles possess *different* properties; such bodies are called *compound bodies*.

We shall be frustrated in all our attempts to obtain sulphur by the mutual fusion of non-sulphurous bodies. In a piece of pure sulphur, on the other hand, it will be equally vain to seek for the least particle of any substance but sulphur alone. The same is the case with many other bodies; for example, we are unable by the aid of the most powerful microscopes to find in gold or iron the least particle of any substance but gold or iron.

Those bodies which are constituted of perfectly *identical* particles are called *elementary* bodies, or briefly *elements*.

3. The number of elements at present known is 63; but many of these are of little importance and rare occurrence. The tabular view annexed affords a statement of such bodies as are of more frequent occurrence, arranged according to their properties. We merely give the names of the others.

The greater number of elements are lustrous bodies, and these we term *metals*. Those which do not possess this property we term *metalloids*, or, more properly, *non-metallic elements*. We also distinguish solid, liquid, and gaseous elements, and amongst the metals such as have only a trifling specific gravity, and others which are more dense.

TABULAR VIEW of ELEMENTARY BODIES.

I. NON-METALLIC ELEMENTS.			II. METALLIC ELEMENTS.					
	I.*	II.		I.	II.		I.	II.
a. Gaseous.			*a. Light.*			*b. Heavy.*		
1. Oxygen	O.	8	14. Potassium	K.	39	21. Iron	Fe.	28
2. Hydrogen	H.	1	15. Sodium	Na.	23	22. Manganese	Mn.	27·6
3. Nitrogen	N.	14	16. Calcium	Ca.	20	23. Cobalt	Co.	29·5
4. Chlorine	Cl.	35·5	17. Barium	Ba.	68·5	24. Nickel	Ni.	29·6
			18. Strontium	Sr.	43·8	25. Copper	Cu.	31·7
b. Liquid.			19. Magnesium	Mg.	12·2	26. Cadmium	Cd.	56
5. Bromine	Br.	80	20. Aluminum	Al.	13·7	27. Bismuth	Bi.	213
						28. Lead	Pb.	103·7
c. Solid.						29. Tin	Sn.	58
						30. Zinc	Zn.	32·6
6. Iodine	I.	127·1				31. Chromium	Cr.	26·7
7. Fluorine (?)	Fl.	19				32. Antimony	Sb.	129
8. Carbon	C.	6				33. Mercury	Hg.	100
9. Sulphur	S.	16				34. Silver	Ag.	108·1
10. Phosphorus	P.	32				35. Gold	Au.	197
11. Arsenic	As.	75				36. Platinum	Pt.	98·7
12. Silicium	Si.	21·3						
13. Boron	Bo.	10·9						

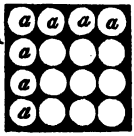
* The letters under I. indicate the symbols of the elements: the numbers in the second row, II., are the proportionate weights in which the elements combine with each other. (See § 15 and 16.)

The names of the rarer elements are as follows:—Beryllium, Cerium, Didymium, Erbium, Iridium, Lanthanium, Molybdanum, Niobium, Norium, Osmium, Palladium, Pelopium, Rhodium, Ruthenium, Selenium, Tantalium, Tellurium, Terbium, Thorium, Titanium, Uranium, Vanadium, Tungsten, Yttrium, Zirconium.

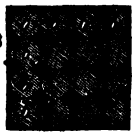
4. *An element by itself is incapable of change.*—We may select any one of the simple substances above mentioned, and so long as it is kept from external contact with other bodies it will retain unaltered its own essential property or character. Sulphur may be, by heat, fused and converted into vapour, but in both conditions it retains its essential properties. Light, electricity, or magnetism are, *per se*, also incapable of changing an element.

5. *Chemical phenomena can be produced only by the contact of at least two dissimilar elements.*—Iron, exposed to moist air, rusts; sulphur and mercury, united by heat, entirely lose their properties, whilst a third body, with new properties, viz., vermilion, appears in their place.

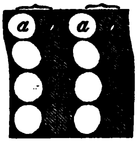
6. The following mode of illustrating the different chemical combinations has been adopted. Simple substances are composed of the minutest particles of matter, which are perfectly homogeneous. Thus the fragment of sulphur, A, fig. 1, is composed of exceedingly minute particles of sulphur, *a* . . . . . and the piece of mercury, B, fig. 2, consists of similar minute particles of mercury *b*. . . . . . Between the particles of one body and the particles of another a mutual *attraction* takes place, which is termed *chemical affinity*.

A


1.

B

2.

In consequence of affinity, a particle of one body is brought into the closest contact with one particle of the other body. During this intimate contact of the different particles their peculiar properties disappear, and a *compound* substance appears, with new qualities. Thus, in fig. 3, the particles of sulphur, *a*, appear in connection with the particles of mercury, *b*, and compose the compound particles, *a b*, of the vermilion.



3.

The particles united by chemical attraction appear, as it were, to be combined together, wherefore the body produced is termed a compound body, or a *chemical compound*, and the different simple elements uniting to compose such a body are called the *constituents* of the compound.

7. Although all bodies have a mutual affinity to each other, still the measure or degree in which different elements are capable of combining is very *dissimilar*, and in the present state of our knowledge we are unable to account for this difference. Suppose, for example, we bring into contact sulphur, iron, and mercury, all of which have a mutual affinity for each other, yet the sulphur will unite with the iron and not with the mercury. And hence the important deduction has been established, namely, that when certain substances are brought into contact with each other, those always first unite which have the greatest mutual affinity.

When simple substances have been thus combined, they remain in this condition till some external operative cause dissolves the union and separates again the different particles that were in intimate connection. It is comprehensible that, in this case, the qualities of the compound body disappear, and that its constituent parts again appear, each with its peculiar characteristics. We signify the separation of the particles of the compound by the term *decomposition*.

8. There are various causes which induce a *decomposition* of chemical combinations. In many compounds the mutual attraction of their constituent parts is so small that little more than a shake is required to effect their separation. For example, a gentle blow on *fulminating silver* is sufficient to cause its instant explosion or decomposition.

Heat is likewise an influential agent in the production of chemical decomposition. While it possesses the property of expanding bodies and of diminishing the cohesion of their particles, it has a tendency to counteract chemical attraction in all cases, and in many to overcome it. When common limestone is burned, that is, when submitted to intense heat, it is essentially changed. A gaseous body (carbonic acid) that previously existed in combination with it, is separated by the influence of the heat. The decomposition of many combinations by *light* is not so easily explicable.

If a *current of electricity* be conducted through a chemical compound, the attraction of the particles is diminished to such a degree, that at present no combination is known which can resist the decomposing influence of a powerful stream. We shall have an opportunity in the sequel of directing our attention more especially to these phenomena.

In the majority of cases of this kind, the *stronger affinity* which one substance has to another, is the active cause of the decomposition of chemical compounds. Suppose, for example, we heat, as shown in § 2, vermilion, which consists of sulphur- and mercury-particles (HgS), with iron (Fe), the latter combines

with the sulphur by reason of its stronger affinity for this element. The particles of iron attract the sulphur-particles from the mercury, and the latter is consequently *released* from its combination, and set at *liberty*, as in figs. 4 and 5.

4.

5.

Whenever we thus employ chemical affinity to the reduction of a compound substance, we obtain, on the one hand, a *new* compound, whilst, on the other, a constituent of the former compound is set free.

9. We will not leave this subject without premising a few reflections intimately connected with a just and perfect comprehension of Nature, and especially of the earth and its manifold aspects.

The earth, together with its atmosphere, forms an entire whole, consisting of a certain number of elements. These elements are present in very unequal quantities, and mostly only in mutual combinations. In this manner have been produced the infinitely-diversified forms and qualities of the objects that surround us. For as, by the various combinations of a few alphabetical signs or letters, an endless series of words that compose the different languages of mankind can be formed, so the few elements, combined in different groups, without exception, constitute the immense variety of objects which everywhere surround us.

There is never so much as a single particle of matter belonging to the earth, nor of any object in or about it, that can be utterly lost. If we burn a piece of wood, we only change or alter the condition of its constituent parts. During the process of combustion, these elementary constituents, instead of remaining solid and ligneous, assume new gaseous and other invisible forms of combination; they disappear to us, but pass not beyond the sphere of our terrestrial atmosphere. When we come to the treatment of the food of plants, we shall prove that the constituent parts of the burnt wood which enter the atmosphere, in the form of new combinations, are again capable of reduction, and of being once more placed in a condition to form ligneous matter.

10. Hence, no particle of matter is ever entirely *annihilated*, and from this it also follows, that we are utterly incapable of *producing*, or of creating, the least material atom. When, therefore, we speak of the *preparation* or *production* of a body, we mean merely the separation of a body from a chemical compound, in which it already exists, or else the formation of the same, from its constituents in certain definite proportions.

A particle of sulphur ever remains the same individual indestructible atom of sulphur; and only in chemical union with other bodies, does it disappear to us, and is incapable of detection by the perceptions of the senses. But when we dissolve this chemical union, it appears again, with all its essential characteristics, being liberated from the combining influence of other substances.

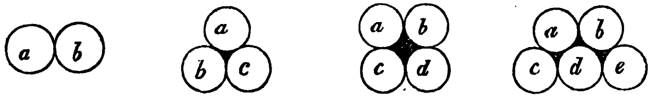
11. Chemical affinity does not manifest itself, under all circumstances, between different elements. There are bodies which have powerful affinities for others, that can remain in contact for years without entering into combination. *Cohesion* is the most powerful obstacle to the operation of chemical attraction. That power which holds the individual particles of a simple body in connection, counteracts the power of affinity, and prevents these particles from losing their coherence, and consequently from entering into combination with other bodies. Hence, it is a general rule, that the greater the power

of cohesion, the less the tendency that exists between any two bodies, to enter into chemical combination. All causes which diminish the cohesion of bodies, promote their capacity for chemically combining with each other. Therefore, heat, which is in very many cases the most efficient medium of weakening the power of cohesion, is brought forward in aid of affinity. This agent reduces many bodies to the fluid state, and renders their particles easily moveable, whereby they are in a condition to follow the action of affinity, and to unite themselves with the particles of another body. *Fluid bodies* are already in this favourable position; hence, they are in a high degree peculiarly susceptible of chemical union. We shall subsequently see that *water* is a very powerful *agent in the reduction of bodies to a fluid condition; that is, to dissolve them, or hold them in a state of solution, by which their particles* are maintained in the requisite degree of mobility.

12. The *gases*, being bodies or substances possessed of little or no cohesiveness, might be supposed to be peculiarly susceptible of chemical attraction, and to combine together with the greatest facility. The case, however, is different from what we should imagine; for example, oxygen and hydrogen, or chlorine and hydrogen, may be brought into mutual contact; yet, except under peculiar circumstances, they are incapable of chemical combination; still they have, notwithstanding, a strong mutual affinity, and their particles being gaseous, possess no cohesion. Consequently, gaseous particles appear to be too widely separated to allow chemical attraction to operate on both with energy sufficient to unite them. Most combinations containing a gaseous element may be decomposed by a higher temperature which increases the expansibility of the gas, and finally overcomes the influence of chemical attraction. We also perceive that the same cause, viz., heat, is in certain cases an auxiliary of affinity, and in others, it counteracts and finally destroys it.

Different kinds of Combinations.

13. Heretofore we have assumed that chemical combination consists in the union of a particle of one simple body with a particle of another simple body. Although hereby indeed a great multiplicity of combinations can be produced, yet this is not the only possible way in which bodies can unite. In a great number of chemical compounds, there are *three*, in others *four*, and in some, *five* different particles in combination. Examples of a greater number of different elements, united in chemical combination, are exceedingly rare.



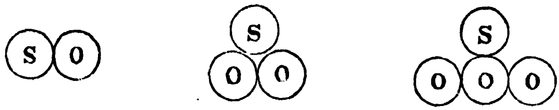
6.

Fig. 6 represents combined, or rather grouped, particles which consist of 2, 3, 4, and 5 simple molecules. It is to be remarked, that by far the greater number of chemical combinations, consist only of two or three dissimilar particles. Those containing four or five are by no means numerous.

It would, however, be erroneous, and contrary to the fact, to infer that the multiplicity of simple materials, capable of uniting with each other is exhausted in the above-cited examples of combination. An infinite series of chemical compounds is disclosed to our view by the capability of the particles chemically

to unite, not only in pairs, but in several other relative proportions. Thus, *one* particle a combines not only with one particle b, but also with $2b$, $3b$, $4b$, nb. Moreover, *several* particles of a can combine with *several* of b, for example, $2a$ with $3b$, $5b$, $7b$, &c. Indeed, frequently we find several particles of three, four, or five different elements grouped together in one chemical compound. To assist the comprehension, we will represent such a group, and then prove the fact by examples. The two elements oxygen O, and sulphur S, form the following *series of compounds* :—

Hyposulphurous Acid. Sulphurous Acid. Sulphuric Acid.



It will be now easy to understand what is meant by the expression *different degrees of combination* of bodies. A glance at the above series will show why sulphurous acid is said to be a *lower*, and sulphuric acid a *higher*, degree of combination of oxygen and sulphur. It is much more difficult to imagine such groups of compound bodies, which consist of *several* particles of *three* or *four* different elements. Before proceeding farther, we may mention, as an example, that an atom of *sugar* is to be considered a group of six particles of carbon, five of hydrogen, and five of oxygen.

14. A compound body may admit of combination with a second body of equally complex composition ; hence, there is formed a compound of the *second order*. Thus, sulphuric acid unites with potassa, and forms a sulphate of potassa (KO,SO_3). When different combinations of the second order are re-combined, there arise those of the *third order*, of which alum ($Al_2O_3,3SO_3 + KO,SO_3$) is an example. The latter combinations are, however, of unfrequent occurrence, and in the course of describing the individual compounds, we may obtain gradually a clearer comprehension of their nature.

15. In order to express chemical compounds, a number of *symbols* have been introduced, which are extremely convenient in the study of chemistry. The initial letters of the Latin names of the elements have been chosen, of which examples are given in the tabular view (§ 3) in the column I. In chemistry, the letter S represents an atom of sulphur, Hg an atom of mercury, and so on. Hence, if the symbols HgS are placed together they represent an atom of a chemical compound of mercury and sulphur, which is called vermilion, in the same manner, as if an atom of mercury and an atom of sulphur HgS were, as in § 8, placed in contact with each other. HgO is the compound of an atom of mercury, with an atom of oxygen (oxide of mercury); SO_2 is a combination of *one* atom of sulphur with *two* of oxygen (sulphurous acid) ; SO_3 indicates the higher proportion in which these elements combine to produce sulphuric acid, consisting of *one* part of sulphur, and *three* parts of oxygen, &c.

16. The elements combine with each other in definite unalterable *proportions by weight*. The tabular view of the simple substances given in § 3 represents in column No. II. these proportionate weights. They are the result of many experiments, conducted with the greatest care and persevering energy. They are termed the *equivalents*, *atomic*, or *proportionate weights* of the elements.

The cause of combination in definite proportions by weight depends chiefly on the principle stated in § 6, viz., that even the smallest particles of bodies have definite weights, varying much from each other. Accordingly, those numbers express nothing more than the weight of one of the minutest particles of each of those simple substances.

Consequently, when an equivalent of sulphur, that weighs 16 parts, combines with a particle of mercury that weighs 100 parts, a compound particle of *vermilion is produced, which weighs 116 parts. In fact, if we decompose* 116 ounces of vermilion into its constituents, we obtain 100 ounces of mercury, and 16 ounces of sulphur. Again, as water consists of one equivalent of oxygen, which weighs 8, and one equivalent of hydrogen weighing 1, the two, combined with each other, represent 9 parts by weight of water. Assuming, therefore, the water to be perfectly pure, it follows that 9 parts will invariably contain 8 parts by weight of oxygen, and 1 part of hydrogen.

If we place the symbol S, which denotes an equivalent of sulphur that weighs 16, and Hg, a particle of mercury, weighing 100, HgS will then represent the compound of the two elements, weighing 116 parts. Hence, chemical symbols have a double value, for they do not merely express of what, and of how many equivalents a compound is composed, but, in addition to this, they indicate the *proportionate* weights in which the elements are held in combination. This may be farther illustrated by an example. The symbol HgO, oxide of mercury, signifies not merely that this compound consists of one equivalent of mercury and one equivalent of oxygen, but also that 100 parts by weight of the former are combined with 8 parts of the latter, to form 108 parts of the oxide of mercury. SO_3 represents *sulphuric acid* as a compound of one equivalent of sulphur, with three equivalents of oxygen, or of 16 parts by weight of sulphur with $3 \times 8 = 24$ of oxygen, which, together amount to 40 parts by weight of sulphuric acid.

As we know at a glance by these symbols, that in 116 parts by weight of vermilion, 100 parts of mercury are combined with 16 parts of sulphur, so we may easily calculate how much of each of these elements is contained in 100, or in 30, or in any assigned quantity by weight of vermilion. Suppose 100 lbs. of vermilion are to be prepared, how many pounds of mercury and sulphur are required for this purpose?

(1.) The quantity of sulphur x is to 100 as 16 is to 116, or:

$$x : 100 = 16 : 116 ; \text{ hence } x = \frac{100 \times 16}{116} = 13 \cdot 7.$$

(2.) The required quantity of mercury y is to 100 as 100 to 116: thus:

$$y : 100 = 100 : 116 ; \text{ hence } y = \frac{100 \times 100}{116} = 86 \cdot 3.$$

Therefore, in preparing 100 lbs. of vermilion, we employ 13·7 lbs. of sulphur and 86·3 lbs. of mercury. These numbers express the *percentage* weight of sulphur and mercury contained in 100 parts of vermilion.

The knowledge of the proportional numbers in which simple substances mutually combine presents still another advantage. Suppose we are required to state how much vermilion can be obtained from 30 lbs. of mercury, when the same is combined with sulphur.

The required quantity of vermilion x stands to the given proportion of mercury, 30 lbs., as 116 : 100, consequently :

$$x : 30 = 116 : 100; \text{ therefore } x = \frac{30 \times 116}{100} = 34 \cdot 8.$$

Thus, if the combination is properly effected, 34·8 lbs. of vermilion ought to be obtained from 30 lbs. of mercury; hence 4·8 lbs. of sulphur are requisite. If less than this quantity of sulphur be employed, the whole of the mercury will not be converted into vermilion. If more than 4·8 lbs. of sulphur be used, the *superfluous* sulphur does not combine with the mercury, but it either remains *mixed* with the vermilion, or it is volatilized by the heat applied during the process of combination. Only those who are ignorant of the law of definite proportions, whereby the elements are capable of combining with each other, could assert that from 30 lbs. of mercury more than 34·8 pounds of vermilion can be prepared. This law of chemical combination is as certain as that 3 and 4 added together amount to 7 and not to 9 or any other number.

Several significant letters placed in contiguity and representing a compound are called a chemical *formula*, the meaning of which, after what has been stated, can present no difficulty to the student. The formula SO_3, therefore denotes the following :—

COMPOSITION OF SULPHURIC ACID.

Formula.		Number of Equivalents.	Constituents.		Combining Proportion.	Percentage Weight.
S	=	1	Sulphur	=	16	40
O_3	=	3	Oxygen	=	24	60
SO_3	=	1 equivalent of Sulphuric Acid		=	40	100

GENERAL PROPERTIES OF CHEMICAL COMPOUNDS.

17. While we direct our attention here to the general properties of chemical compounds, we are not to understand thereby those general properties of bodies which have been already described in Physics (§ 16). On the contrary, we intend to indicate their most general *chemical* characters, particularly the manner in which they deport themselves towards other bodies; if any, and what kind of changes are produced in them.

Three kinds of compounds have been distinguished from an early period in the history of this science, viz., *acids*, *bases*, and *neutral* bodies.

Acids are chemical compounds which have an *acid taste*, impart a *red* colour to vegetable blues (for example, violet and iris), and *lose* their qualities when mixed with a sufficient quantity of one of the compounds of the following class.

Bases (from *basis*, foundation) are distinguished by an *alkaline* taste. A mixture of wood-ashes and lime, with water, produces a substance which has this alkaline property in a high degree. The bases have the power of changing vegetable blues into *green*, and, what is very remarkable, the blue vegetable colour which had been *reddened* by the presence of an acid recovers its *blue tint* on the immission of a sufficient quantity of an alkaline base. On the other

hand, the bases entirely lose their basic characters if allowed to combine with acids.

It must, however, be observed, that there are many acids and bases which either do not possess these properties at all or only in a very slight degree. Insoluble acids, such as silicic acid, and insoluble bases, as the heavy metallic oxides, have no taste, and do not affect vegetable colours. The term *strong* acids and bases is usually applied to such as possess the above-mentioned characters in a remarkable degree.

Thus we perceive that acids and alkalies are bodies possessed of opposite characters, yet in consequence of their mutual affinity, enter into combination with each other, whereby they become neutralized and form new bodies which are neither acid nor alkaline, and are commonly called *salts*.

Such bodies as are neither acid nor alkaline are termed also *neutral* bodies. But the salts are not the only neutral compounds. There is a very numerous class of neutral bodies procured from animal and vegetable substances, such, for instance, as sugar, spirit of wine, albumin, &c.; these latter are likewise called *indifferent* substances, because they exhibit no particular action upon, or affinity to, other substances.

18. We are, however, under the necessity of confining our consideration of the *general* chemical deportment of bodies within a brief compass, until we arrive at the enumeration and description of the individual substances. Still we may be allowed to allude to the important distinction between a mechanical mixture of different substances and a chemical compound of the same, from the confusion of which an erroneous opinion may be frequently formed. However intimately different substances may be mixed together, we may readily distinguish, either by the naked eye or by the aid of a magnifying-glass, the particles of those substances beside each other, whilst in chemical combinations no power whatever will enable us to detect the least difference between the particles of the combined mass. The detection of mixtures of fluids or gases is impossible by vision alone, still the mechanical nature of the mixture may be determined by other means, since the individual components of the mixture *retain* their original qualities, which is by no means the case in chemical combinations.

Division of the Subject.

19. Chemical phenomena have always been divided into *two* principal groups. The reason of this twofold division of the subject will be described hereafter. It is very natural to consider, in the first place, the *simple* and afterwards the more *complicated* combinations: of these we have given examples in § 13, when showing the distinction between the manner in which *two* elements combine to produce vermilion, and *three* to form sugar.

Hence we divide Chemistry into two principal sections, of which the first comprises the combinations of the *simple* groups, and the second the combinations of the *compound* groups.

With few exceptions the latter compounds are either met with in animal or vegetable substances, or are prepared from materials derived from them. Hence the second division of Chemistry is frequently termed *Organic*, or Animal and Vegetable Chemistry, in contradistinction to the first branch, which is called *Inorganic* Chemistry.

The following table will give an idea of the farther division of this branch of natural science:—

(A.) COMBINATIONS OF THE SIMPLE GROUPS. (INORGANIC CHEMISTRY.)	(B.) COMBINATIONS OF THE COMPOUND GROUPS. (ORGANIC CHEMISTRY).
I. *Elements and their Combinations.*	I. *Compound Radicals and their Combinations.*
(1.) Non-Metallic.	(1.) Acids.
(2.) Metallic.	(2.) Bases.
	(3.) Indifferent substances.
II. *Peculiar Decompositions of these Compounds.*	II. *Peculiar Decompositions of these Compounds.*
(1.) By Electricity.	(1.) Spontaneous Decomposition.
(2.) By Light.	(2.) Dry Distillation.

(A). COMBINATIONS OF THE SIMPLE GROUPS.

(INORGANIC CHEMISTRY.)

20. In this section we shall become acquainted with the elements themselves, and of their most simple combinations. These bodies are partly met with in Nature under the form of *minerals*, and are partly prepared by artificial processes (§ 10), in which latter case they are called chemical *preparations*. As the composition of these compounds is tolerably simple, their decompositions and the new *products* thereby produced may be easily understood and predetermined.

I. ELEMENTS AND THEIR COMBINATIONS.

21. At the present time we are acquainted with 63 simple substances; but as every year new members are discovered, we are entirely ignorant of the number actually in existence. It may be remarked that even those substances which we now regard as simple elements may be likewise compounds, and that only a very limited number of bodies are really elementary. Still it is very improbable that we shall ever be able to resolve them into simpler forms of matter, and so long as this cannot be effected we must continue to regard them as simple bodies. A great number are so extremely rare that many chemists have never seen them. It is possible that in the interior of the earth large masses of these bodies occur. We shall, however, refrain from alluding to them, since the majority are entirely foreign to ordinary phenomena.

(1.) NON-METALLIC ELEMENTS.

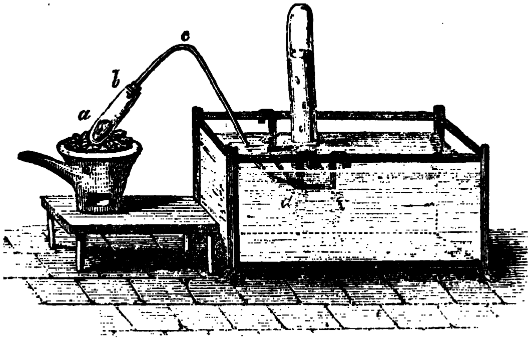
22. Including Oxygen, Hydrogen, Nitrogen, Chlorine, Bromine, Iodine, Fluorine, Sulphur, Phosphorus, Arsenic, Carbon, Silicium, and Boron.

I. OXYGEN.

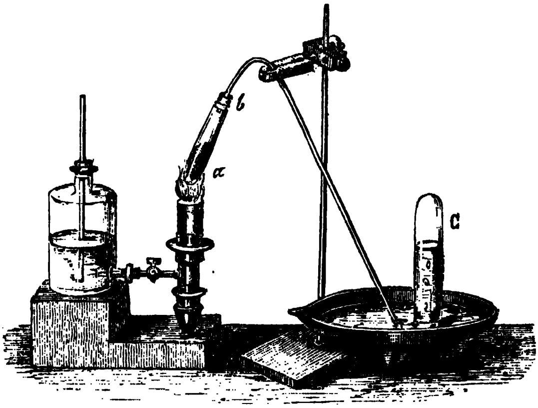
Symbol: $O = 8$; Specific Gravity $= 1{\cdot}1026$.

Oxygen is met with in Nature, either combined or merely mixed with other substances. It may be readily obtained in the pure state from several of its

compounds by the influence of heat alone. The red oxide of mercury is one of the substances which readily part with their oxygen. To prepare oxygen from this compound, a portion of the oxide is introduced into a small tube of hard glass (*a b*, fig. 7) closed at one extremity, and into the other end of which is



fastened, by means of a cork, a delivery tube, *c d*. On applying the heat of a small charcoal furnace, or spirit-lamp as shown in fig. 8, the oxygen is dis-



8,

engaged, and may be collected in the receiver C, which is filled with water, and inverted over the pneumatic trough V.* The change may be represented by the following equation :—

Oxide of Mercury.		Mercury.		Oxygen.
HgO	=	Hg	+	O

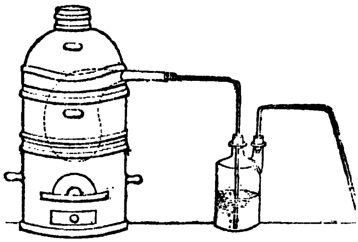
Oxygen may be likewise very conveniently prepared, in a state of perfect

* A similar arrangement to this is made use of for collecting gases in general.

purity, by heating chlorate of potassa (KO,ClO_5) in the same apparatus, the decomposition being expressed as follows:—

Chlorate of Potassa.		Chloride of Potassium.		Oxygen.
KO,ClO_5	=	KCl	+	O_6.

But when this gas is required in very large quantities, it is usual to prepare it from the binoxide of manganese, an oxide occurring abundantly in Nature. This oxide requiring a high temperature, is heated in a retort placed in a furnace (fig. 9), and to which is attached a tube, passing into a wash-bottle, con-



taining a little lime-water for the purpose of absorbing carbonic acid, with which the oxygen may be contaminated. The gas is then collected in the usual manner.

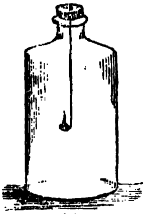
The binoxide of manganese, however, does not part with more than one-third of its oxygen, a mixture of protoxide and sesquioxide of the metal being left in the retort. The following equation represents the change produced by heat:—

Binoxide of Manganese.		Protoxide.		Sesquioxide.		Oxygen.
$3(MnO_2)$	=	MnO	+	Mn_2O_3	+	O_2.

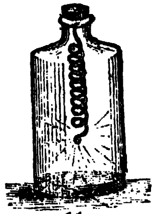
All the green parts of plants evolve oxygen when exposed to the *light of the sun;* a fact which may be readily demonstrated by placing a leafy branch, which is still connected with the parent plant, or a number of fresh leaves, under a stoppered funnel filled with water, and then exposing them to the influence of solar light. After a short time small air-bubbles, consisting of pure oxygen, collect in the upper part of the funnel. The elimination of oxygen observed in many of the so-called *infusoria*, may be also ascribed to plants.

Oxygen is a gas as colourless and odourless as the surrounding air; it is, however, readily distinguished by the extraordinary vivacity with which inflammable substances burn in it. If, for instance, a scarcely-kindled match be plunged into a cylinder filled with oxygen, it instantly bursts into flame, and burns with the greatest rapidity. Phosphorus burns with a dazzling white light, rivalling the sun in brilliancy, whilst sulphur burns with a beautiful blue flame. Pieces of charcoal, and thin strips of steel, to which are attached pieces of amadou dipped in sulphur, if previously ignited at the extremities, and

then introduced into this gas, as in figs. 10 and 11, throw off the most beautiful scintillations, and are entirely consumed.



10.



11.

These phenomena depend upon the powerful affinity of oxygen gas for those substances. Hence combustion itself is nothing more than the effect of their combination with the latter element. The compounds formed in the above-mentioned experiments are carbonic acid (CO_2), sulphurous acid (SO_2), phosphoric acid (PO_5), and sesquioxide of iron ($Fe_2 O_3$).

Oxygen is not only the most extensively-diffused element, but it occurs in the largest quantity. It is contained in by far the greatest number of minerals, and forms from 30 to 50 per cent of the entire mass of plants and animals, whilst 112 lbs. of water contain 100 lbs., or eight-ninths of its weight of this gas. It may be said to constitute a third of the known crust of the earth.

It is also important to remark, that the principal mass of the atmosphere is a *mixture* of oxygen with another gas, viz., nitrogen. Five measures contain one of oxygen, and hence it forms one-fifth of the whole atmosphere.

From this it will be seen that all bodies existing in the air are exposed to the influence of the oxygen therein, which exhibits a continual tendency to produce chemical compounds with those substances which are not at all, or only partly, in combination with this gas. Hence it is the cause of an endless series of chemical phenomena which are ever going on around us, and within our bodies. If circumstances are particularly favourable, chemical combination takes place with a rapidity sufficient to generate a large amount of heat, and finally light, or, in other words, those phenomena occur that are ordinarily termed *combustion*. But in far the greater number of cases, the combination of oxygen takes place more slowly, and unattended with the phenomena of ignition. Heat, however, is undoubtedly generated, but becomes less evident in consequence of being distributed over a greater space of time. The rusting of iron, formation of verdigris on copper, fermentation, putrefaction, decay, moulding, disintegration, respiration of men and animals, are all phenomena primarily induced by oxygen. In all these cases new oxygen-compounds are produced; but if the oxygen were excluded none of these changes could be effected, any more than a body could burn without the presence of the atmospheric air which contains so large an amount of oxygen.

23. Combination with oxygen is also termed *oxidation*. To *oxidise*, therefore, is to unite with oxygen, and the result of the combination is named an *oxide* or oxygen-compound. But as oxygen is capable of combining in several proportions with most of the above elements, the different *degrees of oxidation* are distinguished by a particular name, as is seen in the following examples.

Oxygen, in combination with non-metallic elements, chiefly forms *acid*, with metals, *basic*, oxides. An elementary body combining with oxygen, and forming therewith an oxygen-compound, is generally designated by the term *radical* of such a combination; for example, sulphur is the radical of sulphuric acid ($S O_3$).

The general properties of oxygen-compounds are most conveniently exhibited in the following Table:—

Synopsis of Oxygen-Compounds.

1. Bases.

Degree of Oxidation.		Examples.	Formulæ.	General Properties.
1	*a.* Suboxides -	Suboxide of Mercury Suboxide of Copper	Hg_2O Cu_2O	Feeble bases; are separated from their combinations by most of the other oxides; absorb oxygen with avidity from the atmosphere, and are converted thereby into higher oxides.
	b. Protoxides -	Protoxide of Iron - Protoxide of Manganese - - -	FeO MnO	
2	*a.* Protoxides -	Protoxide of Mercury Protoxide of Potassium - - - Protoxide of Sodium	HgO KO NaO	Strong bases; frequently caustic; do not pass into a higher state of oxidation when exposed alone to the air. The oxides of the heavy metals are insoluble in water.
	b. Sesquioxides	Sesquioxide of Iron Sesquioxide of Manganese - - -	Fe_2O_3 Mn_2O_3	
3	Binoxides -	Binoxide of Manganese - - - Binoxide of Lead -	MnO_2 PbO_2	Neither acid nor basic; decomposed by heat into lower oxides and oxygen.

2. Acids.

	c. First degree	Hyposulphurous Acid	S_2O_2	
1 (4)	Second degree	Sulphurous Acid - Nitrous Acid - - Chlorous Acid - - Phosphorous Acid -	SO_2 NO_3 ClO_3 PO_3	Feeble acids; separated from their combinations by most of the other acids; attract oxygen from the air, and become thereby converted into acids of the fourth degree of oxidation.
	d. Third degree	Hyposulphuric Acid	S_2O_5	
2 (5)	Fourth degree	Sulphuric Acid - - Nitric Acid - - - Chloric Acid - - Manganic Acid - -	SO_3 NO_5 ClO_5 MnO_3	Strong acids; frequently caustic; mostly unchangeable in the air, some being decomposed by heat like the following.
3 (6)	Highest degree	Perchloric Acid - Permanganic Acid -	ClO_7 Mn_2O_7	Feebler than the foregoing acids; readily decomposed by heat into oxygen and a lower degree of oxidation.

24. In addition to these six principal degrees of oxidation, chemists are acquainted with a number of intermediate compounds which in general are feebler acids, and more readily decomposed; examples of this kind are adduced under *c* and *d*, namely, hyposulphurous acid (S_2O_2), and hyposulphuric acid (S_2O_5). In the same manner we find amongst the metallic oxides a number of intermediate combinations possessing no definite chemical characters.

Although the non-metallic elements, in combining with oxygen, give rise in

general to the formation of *acids*, we nevertheless meet with a number of inferior oxides possessing properties neither acid nor basic, as, for example, water (HO), protoxide of nitrogen (NO), carbonic oxide (CO), and many others. On the other hand we find that while most of the metallic oxides are *bases*, some of the higher oxides comport themselves as acids, as manganic acid (MnO_3), chromic acid (CrO_3), antimonic acid (SbO_5), &c.

From these examples it will be seen that the name and position of the oxide are determined not by the *number* of equivalents of oxygen, in combination with the radical, but by its *chemical* properties; as, for instance, sulphuric acid, containing only *three* equivalents of oxygen, is a stronger acid than nitric acid, which contains *five* equivalents of the same element.

25. An opinion was long prevalent that oxygen was the only acidifying principle, and from this supposed quality its name was derived. But as it has subsequently been ascertained that there are very strong acids which contain no oxygen, and also that this body, in combination with metals, forms the strongest bases with qualities directly opposed to acids, the term has lost the major part of its signification. On this account the acids which contain this element are now distinguished by the term *oxygen-acids.*

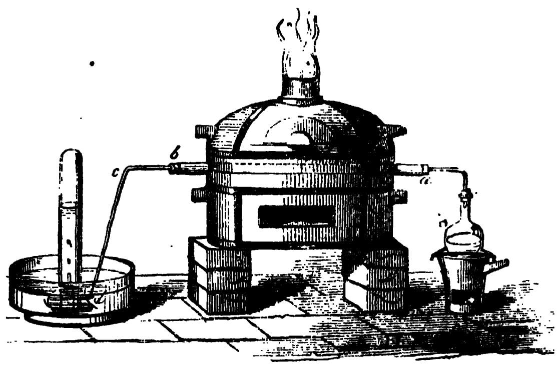
Oxygen is, however, justly accounted the principal, the most important and influential of all elementary bodies. It merits this preference by its abundance, its powerful affinities, and by its manifold combinations with other substances.

2. HYDROGEN.

Symbol: H = 1; Specific Gravity = 0·0688.

26. Hydrogen occurs abundantly in nature, although it is never met with in the free state. It is found in the greatest quantity united with oxygen, forming a compound (HO) termed *water*, which, as is well known, is extensively diffused over the surface of our globe. We invariably avail ourselves of this compound in preparing the pure gas.

Hydrogen is obtained by heating water in a small flask, and passing its vapour through a red-hot gun-barrel, filled with iron nails (*a b*, fig. 12), to



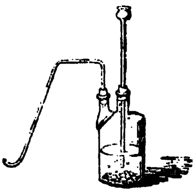
12.

which is attached, by means of a cork, a delivery-tube, *c d.* The oxygen of

the water combines with the iron, and produces sesquioxide (Fe_2O_3), while the hydrogen escapes at the curved extremity of the delivery-tube, *c*, and may be collected in the usual manner. The decomposition of the water is thus represented by an equation:—

Water.		Iron.		Sesquioxide of Iron.		Hydrogen.
3HO	+	2Fe	=	Fe_2O_3	+	3H.

Hydrogen is, however, more conveniently prepared by introducing pieces of granulated zinc into an apparatus (fig. 13) which is termed an evolution-flask, and pouring over them a mixture of water and sulphuric acid. The products formed from Zn, HO, and SO_3, are hydrogen, H, evolved in the form of gas, and sulphate of zinc, ZnO,SO_3, which remains in the flask.



13.

Zinc.		Hydrated Sulphuric Acid.		Sulphate of Zinc.		Hydrogen.
Zn	+	HO,SO_3	=	ZnO,SO_3	+	H.

In these two cases the decomposition of water depends upon the affinity of oxygen for iron and zinc.

Hydrogen is a colourless, odourless gas, that *ignites* when approached by flame, and *burns* with a feeble light, but with development of much heat. It thus combines with the oxygen of the atmosphere and produces water HO. As one volume of hydrogen weighs fourteen times less than an equal bulk of atmospheric air, it follows that silk balls that are filled with this gas will ascend in the atmosphere, precisely in the same manner as a cork will rise in water. For the purpose, however, of inflating the larger air-balloons, the cheaper carburetted hydrogen (coal-gas) is invariably employed.

Hydrogen has at present received no particular application in the arts, although it is sometimes employed for increasing the intensity of the forge-fire. If we sprinkle water upon red-hot coals it is thereby decomposed, the oxygen combines with the carbon to form carbonic acid, while the liberated hydrogen burns and developes a very high degree of heat.

When hydrogen is passed over an ignited metallic oxide, for instance over protoxide of copper (CuO), it combines with the oxygen of the latter, producing water, which escapes in the form of vapour, whilst the pure metal remains behind. This mode of withdrawing oxygen is termed *deoxidation*, and is frequently employed by chemists.

Compounds of Hydrogen.

27. Hydrogen combines chiefly with the non-metallic elements, scarcely any combinations of this element with metals being at present known. From 5 to 6 per cent of hydrogen is found in all vegetable and animal matters.

With chlorine, bromine, iodine, fluorine, sulphur, and some other bodies, this element produces acid compounds, which have received the name of *hydrogen-acids*. Its most important combination, however, is:—

WATER.

Formula: $HO = 9$; Specific Gravity $= 1$.

28. When 12 parts by weight of hydrogen and 100 of oxygen, or, what is the same, two measures of the former gas and one of the latter, are mixed *together, no combination* occurs, for under these circumstances they are *incapable of uniting*. Their union, however, is instantaneously effected when the mechanical mixture is brought into contact with an ignited body. The combination is attended with a violent explosion, that is, a flash and loud report, both occasioned by the aqueous vapour being enormously expanded by heat at the moment of its formation. This gaseous mixture has therefore received the name of *explosive gas*, and to avoid the danger attending experiments it should always be prepared in small quantities. By means, however, of a suitable apparatus, a larger quantity of this explosive gas may be burned, and the water, formed during the combustion, collected in sufficient quantity to convince the experimenter that it possesses all the properties of the purest water.

As we are well acquainted with most of these properties, partly through daily experience and partly through physics, we intend to state here only the *chemical* qualities of water. Although neither acid nor basic, but in a high degree neutral or indifferent, water nevertheless possesses a powerful affinity for many chemical compounds, and more especially for acids and bases. Its compounds with these bodies are termed *hydrates*. In the formation of hydrates a development of heat generally takes place, and is occasioned by the water passing into a denser condition, a portion of its combined heat being simultaneously evolved (Physics, § 146). Examples of this kind are the development of heat in mixing strong sulphuric acid with water, and in the slaking of lime.

The acids are more frequently employed in the form of hydrates, as, for example, hydrated sulphuric acid (HO,SO_3) than in the anhydrous condition; and when the latter are not specially indicated the hydrates are usually understood to be meant when speaking of acids. The *water of hydration* does not admit of being separated from acids by heat, but only by the superior affinity of a metallic oxide.

The bases, or metallic oxides, occasionally acquire peculiar colours in combining with water. Sesquioxide of iron is red, whilst its hydrate is brown; protoxide of copper is black, its hydrate a beautiful blue. Most oxides part with their water of hydration on application of heat, some at a lower, others at a higher temperature. Hydrate of potassa, KO,HO, and hydrate of soda, NaO,HO, however, do not lose their water when exposed even to the strongest red-heat.

Water combines also with salts, forming with their particles solid crystals, and in this state it is termed *water of crystallization*. We perceive in salts and in hydrates that water may be reduced to the *solid* condition not only by low temperatures, but also by chemical affinity; *anhydrous* salts are therefore distinguished from such as contain water of crystallization. The compound NaO,SO_3 is anhydrous sulphate of soda, while NaO,SO_3+10HO is the same salt combined with ten equivalents of water. The greater number of salts, however, part with their water in dry air or when exposed to a temperature of 100° C. (212° F.) In this case the particles of water escape from between

the molecules of the salt, which then crumbles down, and exhibits the phenomenon termed *efflorescence* of crystals.

29. Water possesses the remarkable property of *dissolving* a great variety of substances; but solution appears to be less the result of chemical affinity than of the great attraction the water-atoms possess for those of the soluble body. The former penetrate through the particles of the latter, and destroy their coherence. Solution appears not to induce any change in the chemical properties of a substance, for on application of heat the water is expelled, and we recover the particles of the dissolved substance, with all its original cohesive properties unchanged.

When to the solution of any substance a new portion of the same is added, without becoming dissolved, the solution is said to be *saturated*, but in general the liquid takes up an additional quantity of the soluble substance, if the temperature be increased. If this solution be now cooled, a portion of the dissolved substance is usually separated in *crystals* of definite form (Physics § 19). Solution is therefore the means of obtaining bodies in the *crystallized* state. If, on the other hand, a dissolved body is suddenly made to pass from the liquid to the solid state, as, for example, when a hot saturated solution is suddenly cooled, the salt does not separate in the form of distinct crystals, but as an *amorphous precipitate*. The latter form is also produced on adding to the solution a substance which produces an *insoluble* compound. If to a solution of baryta (BaO), in water, we add sulphuric acid, the two compounds combine to produce the insoluble sulphate of baryta (BaO,SO_3), which is immediately deposited at the bottom of the vessel, in the form of a white precipitate.

It is upon the solubility of some compounds, and insolubility of others, the possibility of separating many substances from each other depends, and hence their deportment with water is to the chemist a most important characteristic.

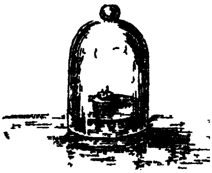
30. The solvent properties of water are the true causes why we never obtain this universal and important fluid in natural and domestic economy in a state of *purity*. It constantly participates in the properties of the manifold sources whence it is derived, or through which we obtain it. Whenever it is in contact with the soil it invariably dissolves the soluble constituents; and hence it follows that water springing from rocks which are only slightly soluble, as sandstone and granite, is very pure, and is called *soft water*, while that which is derived from calcareous formations is termed *hard water*, and contains a deal of lime, which produces an incrustation on the sides and bottom of the vessel wherein it is boiled. The water of springs which have their source at a greater depth possesses a higher temperature, reaching in some instances to the boiling heat; these sources have received the name of *thermal springs*. If water meets, on its passage through the soil, with carbonic acid, hydrosulphuric acid, salts, &c., a portion of these compounds enter into solution, and impart to the water peculiar properties, such as are exhibited in the waters of *mineral springs*. Sea-water contains in solution so many salts, especially common salt and sulphate of magnesia, as to be entirely unfit for the ordinary purposes of life.

Water, distilled from a retort (Physics, § 129), is free from all non-volatile substances, and next to it in point of purity ranks that which is distilled in Nature's laboratory, viz., rain. The latter is therefore especially employed in many of the arts which require pure water, as in dyeing, washing, &c.

3. NITROGEN.

Symbol: N = 14; Specific Gravity = 0·976.

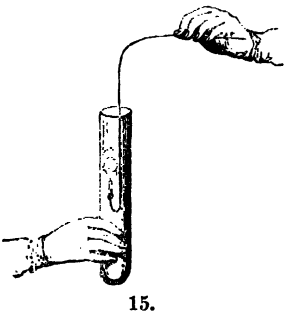
31. Five volumes of common air contain four of nitrogen, mixed with one of oxygen; this element, therefore, constitutes four-fifths of the entire atmosphere. The proportion of nitrogen in the solid portion of the earth is very small; it is rare in mineral, and only sparingly found in vegetable substances; but it is more abundant in animal bodies. Nitrogen may be easily prepared in the following manner: A large flat cork is floated on the surface of the water in the pneumatic trough. On this is placed a small porcelain capsule, containing a fragment of phosphorus, which is ignited and then immediately covered over by a large bell-jar as shown in fig. 14. The jar being immersed about an inch deep in the water, prevents the air from escaping. The burning phosphorus combines with the oxygen of the air contained in the bell-jar and produces phosphoric acid (PO_5), which is dissolved by the water, while nitrogen, amounting to four-fifths of the air in the bell-jar, remains.



14.

It is, however, more convenient to employ, instead of the phosphorus, a few drops of naphtha or spirit of wine, since the vapours of phosphoric acid remain some time before they are dissolved by the water, while the little carbonic acid produced by the combustion of the naphtha in no way interferes with the results of the experiment.

This gas is odourless and colourless, and not injurious to health, for large quantities are continually taken into the stomach and lungs in the processes of respiration and deglutition. If a burning body be introduced into a cylinder of pure nitrogen as in fig. 15, it is instantly extinguished, and animals placed therein soon die from the want of oxygen which is indispensable to their respiration.



15.

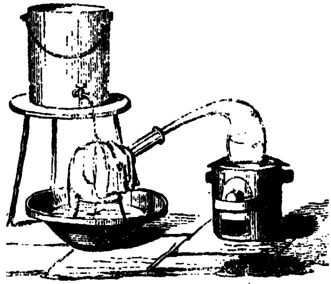
32. The *atmosphere* contains, moreover, many volatile substances, such as *carbonic acid*, to the extent of 4 volumes in 10,000, and aqueous vapour, which varies in quantity according to the temperature (Physics, § 132). On the other hand, many impurities, such as those arising from the exhalations of men, animals, and decaying matter, escape into the almost illimitable atmosphere. The presence of these substances can, therefore, only be detected and chemically ascertained at the place of their formation.

Compounds of Nitrogen.

33. Nitrogen possesses only a feeble affinity for other substances. With many, especially with metals, it does not appear to combine, and its compounds with the other elements are all very readily decomposed.

Nitric Acid, HO,NO_5.—This acid is obtained in the form of hydrate, by

distilling in a glass retort (fig. 16), 1 lb. of nitre with an equal weight of sulphuric acid. The pure acid is colourless, of peculiar odour, and caustic acid taste; it imparts a yellow colour to vegetable and animal substances, and finally destroys them. It also dissolves most of the metals, a property dependent upon the readiness with which its oxygen combines with other elements, hence nitric acid is frequently employed by the chemist as a *means of oxidation*. In pro-



16.

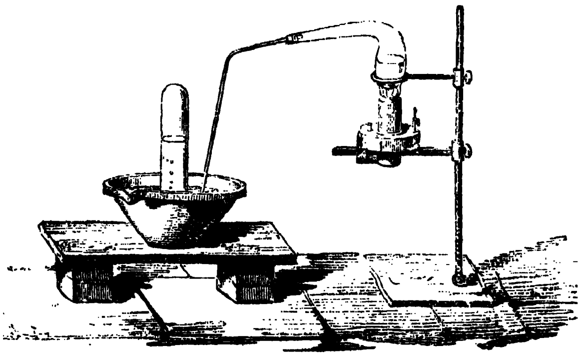
cesses of this nature, the acid loses three equivalents of oxygen, a compound NO_2 being produced, which is a colourless gas, and is called *binoxide of nitrogen*. This gas has the remarkable property of instantly absorbing oxygen from the air, and becoming thereby converted into the brownish-red vapour of *nitrous acid*, NO_3, which possesses a highly-suffocating odour. Nitrous acid in contact with water decomposes into binoxide of nitrogen and nitric acid, as is shown in the following equation :—

$$3NO_3 + nHO = NO_5 + 2NO_2 + nHO.$$

The peculiar behaviour of binoxide of nitrogen in contact with the air and of nitrous acid in the presence of water, is of great practical importance in the manufacture of sulphuric acid, as will be subsequently shown.

Nitric acid is employed in medicine as a caustic, also in dyeing, and for dissolving and separating metals. The acid of commerce, termed *aquafortis*, is never perfectly pure, and is, to a certain extent, diluted with water.

Protoxide of Nitrogen (NO). This, the lowest oxide of nitrogen, is prepared in the following manner:—Nitrate of ammonia is heated in a small glass retort (fig. 17), furnished with a bent glass tube dipping into a pneumatic trough



17.

filled with *warm* water. The substance fuses and enters into ebullition, evolv-

ing a large quantity of gas which may be collected in the usual manner. The decomposition will be rendered intelligible by the following equation :—

$$\underset{\text{Nitrate of Ammonia.}}{NH_4O,NO_5} = \underset{\text{Protoxide of Nitrogen.}}{2NO} + \underset{\text{Water.}}{4HO.}$$

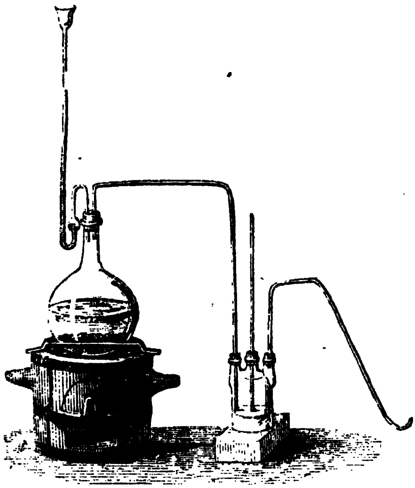
The protoxide of nitrogen is a colourless, odourless gas, having a somewhat sweetish taste. It is a powerful supporter of combustion, and a piece of ignited charcoal will burn in it almost as brilliantly as in oxygen. When respired this gas produces a kind of intoxication of a most exhilarating character, accompanied by very agreeable sensations, hence it has commonly received the name of *laughing-gas.*

34. *Ammonia,* NH_4O.—This compound of nitrogen and hydrogen possesses all the properties of a powerful base; it will be therefore described with the metallic oxides.

4. CHLORINE.

Symbol: $Cl = 35 \cdot 5$; Specific Gravity $= 2 \cdot 44$.

35. Chlorine occurs almost exclusively in the mineral kingdom, and mostly in combination with sodium, with which it produces the compound known to every one as *culinary salt,* and termed by chemists chloride of sodium, NaCl. In the free state, chlorine is obtained by heating hydrochloric acid with binoxide of manganese, as shown in fig. 18.



18.

Chlorine differs remarkably from the gases hitherto described. It possesses a slightly greenish-yellow colour, and a peculiarly suffocating odour. When inhaled, it attacks the lungs violently, and hence, it must be considered as highly pernicious; and all experiments with this gas should be conducted with the greatest care. Chlorine is soluble in water, to which it imparts its properties (chlorine-water).

Compounds of Chlorine.

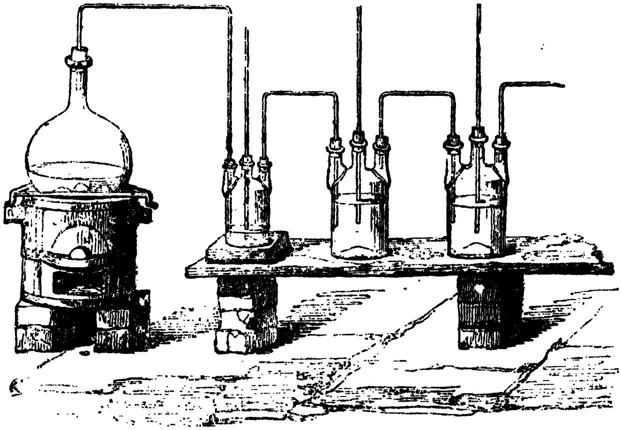
36. Chlorine possesses a remarkably powerful affinity for other substances, exceeding, in many cases, even that of oxygen. It attacks gold and all the other metals, and is especially distinguished by its great attraction for hydrogen. Wherever it meets with this element, in combination with other substances, it displays a remarkable tendency to withdraw it, and to produce hydrochloric acid (HCl.); and as all vegetable and animal substances contain hydrogen (§ 27), they are destroyed without exception, when exposed to the influence of this gas, but if in contact for a shorter period, the surface only is attacked. This pernicious property of chlorine, however, admits of many highly-valuable applications. Most of the colouring matters of the vegetable

kingdom, as well as the fetid exhalations, so prejudicial to health, which arise from decaying animal and vegetable substances, contain hydrogen, and if brought into contact with chlorine, are immediately destroyed by the withdrawal of their hydrogen.

This property, therefore, renders chlorine available in the process of bleaching and in that of purifying air, a subject to which we shall again return.

(1.) *Chloric Acid* (ClO_5) and *Chlorous Acid* (ClO_3).—These acids are employed only in combination with bases, and will be subsequently described.

(2.) *Hydrochloric Acid* (HCl.)—This compound is obtained in solution when common salt is treated with sulphuric acid, and the evolved gas passed into water, until the latter is saturated. In order to prepare the liquid acid, equal parts of common salt and concentrated sulphuric acid, diluted with a third of its weight of water, are introduced into a large flask (fig. 19), and the mixture



19.

heated on a charcoal furnace. The flask is connected by means of a glass tube, with a wash-bottle, containing a small quantity of water, in order to retain a little sulphurous acid, with which the gas may be contaminated. In connexion with this are two other tubulated bottles of larger dimensions, and three-fourths filled with cold water, by which the gas is condensed. This method of preparing hydrochloric acid is thus expressed in an equation :—

Chloride of Sodium.		Hydrated Sulphuric Acid.		Sulphate of Soda.		Hydrochloric Acid.
$NaCl$	+	HO,SO_3	=	NaO,SO_3	+	$HCl.$

The liquid thus obtained possesses the odour and taste of a strong acid, but is less destructive in its effects than either sulphuric or nitric acid. In the manufacture of soda, this acid is obtained in enormous quantities as a waste product, and usually possesses a yellow colour, which is caused by contamination with iron. Its applications are very numerous, being used in medicine, in many chemical operations, and especially in the preparation of chlorine. When mixed with nitric acid, it forms the so-called *aqua regia*, which is employed for dissolving gold.

When equal measures of chlorine and hydrogen are mixed together, and

exposed to the direct light of the sun, they instantly combine, and give rise to a violent explosion. In the shade, however, or by candle-light, these gases may be mixed in a flask without danger. This is one of the most beautiful chemical experiments.

5. BROMINE.

Symbol: Br = 80; Specific Gravity = 2·966.

37. Bromine is one of the rarer elements, being found only in small quantities, combined with sodium and magnesium, in the salts of sea-water, and of many saline springs, especially those of Kreutznach, in which it occurs in the largest quantity.

When prepared in the pure state, it forms a dark-brown, reddish liquid, of peculiar odour, resembling that of chlorine. It has, at present, received no application in the arts; but it appears to impart particular medicinal properties to the waters in which it is found, and for which reason it deserves to be mentioned.

6. IODINE.

Symbol: I. = 127·1; Specific Gravity = 4·97.

38. Iodine occurs more frequently than the body just described, but it is nevertheless considered as one of the rarer elements. It is found in combination with sodium and magnesium, in sea-water, and in almost all marine plants and animals. It is also contained in many springs. This element is the first solid body we have to describe; its colour is grayish-black, and it is almost as lustrous as black-lead; it possesses a peculiarly disagreeable odour, somewhat similar to that of chlorine, and it imparts a brown colour to the skin and to vegetable substances when left in contact for a considerable time. By heat it is converted into a beautiful violet vapour, which, on cooling, solidifies again into small black plates. Iodine is likewise distinguished by producing with starch a deep violet colour, which furnishes us with an excellent test for recognising the presence of the one or the other.

Iodine is poisonous in the free state as well as in combination with metals, but it nevertheless forms an important remedial agent which exerts a specific influence in diseases of the glands, bronchocele, and scrofula. The medicinal properties of cod-liver oil and burnt sponge are chiefly due to the presence of iodine. If iodine be dissolved in spirits of wine, and the solution mixed with aqueous ammonia, a black precipitate is obtained, consisting of iodine and nitrogen. When this compound is dried, the slightest friction instantly decomposes it into its constituents, with violent explosion. In making this experiment, it is therefore necessary to operate on the small scale and to proceed with the greatest care.

7. FLUORINE.

Symbol: Fl = 19; Specific Gravity = 1·28.

39. Fluor-spar is a mineral occurring in many places, but not in large quantities; it is a compound of fluorine and calcium (CaFl.) The element fluorine is a gaseous body, extremely difficult to prepare, on account of the great facility with which it combines with other substances; it is especially distinguished by its powerful affinity for silicic acid, with which it instantly combines when brought into contact. All glass contains silicic acid, and is

attacked and decomposed by most of the fluorine compounds, we therefore avail ourselves of this property in etching upon glass, a process conducted in the following manner.

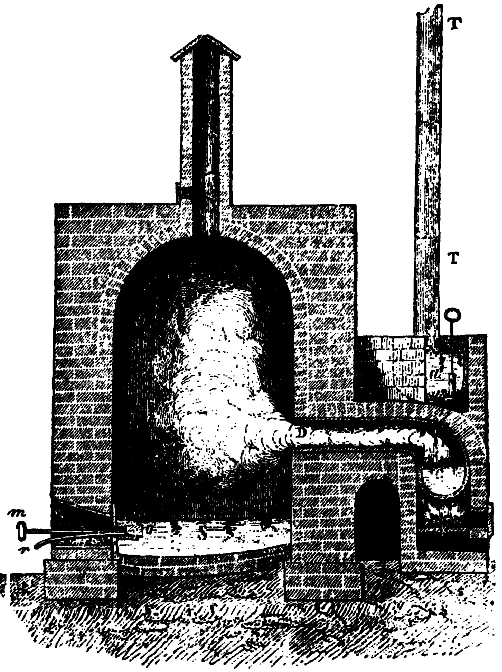
A plate of glass is covered with a thin coating of wax, and blackened by holding it over the flame of a candle, the design being then traced upon the surface with a needle. The plate thus prepared, is now placed over a leaden vessel of sufficient size, containing a mixture of pulverized fluor-spar and sulphuric acid, which is gently warmed. The pungent, acid-smelling vapour of hydrofluoric acid (HFl) is evolved, and attacks the glass wherever it is bare. After 10 or 20 minutes, the plate is removed, and gently warmed, in order to free it from wax, when the etching becomes distinctly visible. The vapours of hydrofluoric acid are, however, very pernicious, and attack even the skin: the greatest care is therefore required.

Bromine, iodine, and fluorine form with oxygen and with hydrogen classes of compounds analogous to those of chlorine.

8. SULPHUR.

Symbol: S = 16 ; Specific Gravity = 2.

40. In Sicily and the neighbourhood of Naples, are found large masses of pure *native* sulphur, between limestone and marly clay. As obtained, however, it is never perfectly free from earthy matters, and it has therefore to be *refined* or purified.

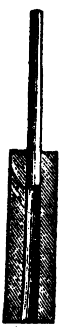


20.

This process is effected in a retort of brass or iron, GD, fig. 20, communicating with a large brick chamber, A, which serves the purpose of a receiver. The retort is placed over a furnace, the grating of which is seen at K. The vapour of the sulphur generated in the retort passes through the tube D into the chamber, where it condenses in the form of a fine powder, which is known as *flowers of sulphur*. The chamber is furnished with a valve, *s*, to allow the heated air to escape, and at the same time to prevent the ingress of the external air of the atmosphere. In the arrangements formerly in use, it was necessary, in order to charge the retort, to open the door, whereby explosions were fre-

quently occasioned by the mixture of air with the heated vapour of sulphur. This danger is now avoided, by placing outside the furnace a reservoir, *a*, which is heated by the hot air of the furnace during its passage to the chimney, T T. This vessel is connected with the retort by the pipe, *v*, closed by a plug. The crude sulphur, as it melts, becomes deprived, to a certain extent, of foreign matters, which settle to the bottom, the fused sulphur, already partly purified, being admitted through the tube into the retort. When the operation is completed, the fused sulphur on the floor, S, of the chamber is drawn off through the small channel, *r*, whose aperture had been closed by means of a plug, *m o*. The sulphur is then cast into cylindric wooden moulds, as shown in fig. 21, and in this form constitutes the roll sulphur of commerce.

Sulphur is also frequently met with in other places, chiefly, however, in combination either with metals, as in iron pyrites (FeS_2), copper pyrites (CuS), &c., or combined with oxygen, as sulphuric acid in sulphate of lime (CaO,SO_3), which forms entire mountains. It is, moreover, frequently met with in vegetable and animal matters, particularly in all albuminous substances, or generally in such as evolve the odour of rotten eggs when suffering decomposition.



21.

The ordinary properties and applications of sulphur are well known. It is used in taking casts of medals, in the manufacture of matches and sulphur threads, and also in medicine, besides a variety of other purposes which have yet to be mentioned. This element fuses at 108° C. (226·4° F.), and at 316° C. (700° F.) is converted into a reddish vapour: in water and most other liquids it is insoluble, although it dissolves in hot linseed-oil, and oil of turpentine; it is, moreover, soluble in bisulphide of carbon (see § 60), from which it may be obtained in beautifully-crystallized double pyramids. When rubbed with cotton, the sticks of sulphur acquire electrical properties.

Compounds of Sulphur.

41. Chemistry and the arts are indebted to sulphur for one of the most important compounds.

(1.) *Sulphuric acid.*—This acid is always employed in the form of hydrate, HO,SO_3, (§ 28). Its preparation is carried on in extensive manufactories, where sulphurous acid (SO_2), nitrous acid (NO_3), and aqueous vapours (HO) are mixed together in large leaden chambers.

Sulphurous Acid.		Nitrous Acid.		Water.		Hydrated Sulphuric Acid.		Binoxide of Nitrogen.
SO_2	+	NO_3	+	HO	=	HO,SO_3	+	NO_2

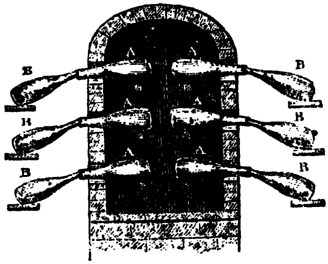
The above equation illustrates the formation of *hydrated sulphuric acid*, which collects on the bottom of the chambers while *binoxide of nitrogen* remains. If at this stage of the process an additional quantity of steam, sulphurous acid, and atmospheric air (N_4O), be admitted into the chamber, the binoxide of nitrogen absorbs oxygen from the air, and is converted into nitrous acid (see § 33). We thus again obtain the requisite mixture for the farther formation of sulphuric acid. In this manner the process may be carried on without intermission. The acid, however, as prepared in the leaden chambers, is diluted with too large an amount of water, and is, therefore, afterwards

heated in a platinum-still, when the water is expelled, and a concentrated acid remains, which at the ordinary temperature has a specific gravity of 1·85, and boils only at 326° C. (618·8° F.) Although the stills of platinum employed for this purpose are very costly, varying in value from 1,000*l.* to 2,000*l.*, they are, nevertheless, preferred to glass retorts, on account of their durability.

The hydrate of sulphuric acid is a colourless, odourless, highly caustic, acid liquid, and is distinguished by its power of combining with a farther quantity of water. It withdraws water from moist air, as well as from vegetable and animal substances, whereby the carbon contained in the latter becomes at once evident. Almost all organic substances, when acted upon by sulphuric acid, are instantly blackened, and forthwith entirely carbonized and destroyed. It is, therefore, in the hands of the careless and inexperienced, a very dangerous liquid.

Sulphuric acid dissolves most of the metals, and possesses so powerful an affinity for the metallic oxides, that it is capable of displacing almost all the other acids when they are in combination with bases. It is, therefore, employed in the preparation of most of the acids, for example, of nitric, phosphoric, acetic, hydrochloric, and many others. It may be considered as the basis of all chemical manufactures; and so important is it in the arts, that, in the year 1840, this country was on the point of declaring war against Naples, when she beheld, for the moment, her entire industry endangered by the restrictive measures of the government of that country, which burdened sulphur with excessive export duties. An idea may be formed of the extraordinary consumption of this acid when it is mentioned that in a single manufactory in Glasgow, that of Messrs. Tennant and Co., upwards of 6,000 tons are annually produced. The price of soda, soap, hydrochloric acid, chlorine, matches, stearin candles, calico, paper, &c., stand in the closest connection with that of sulphur; and it may be justly asserted that the total consumption of this acid in any country is a sure test of its industrial capabilities. As the acid was first manufactured in England, it is termed on the continent *English* sulphuric acid.

Fuming sulphuric acid, which is a mixture of anhydrous acid and the hydrate, $= SO_3 + HO,SO_3$, distils over when sulphate of protoxide of iron (or, as it is usually termed, green vitriol) is first roasted, and then strongly heated in an earthen retort. In the neighbourhood of the Hartz Mountains where this acid is chiefly manufactured, the dried vitriol is introduced into earthen retorts (A, fig. 22), several of which are arranged in a furnace, and gradually heated. As soon as white vapours appear, the receivers, B, containing a small quantity of common concentrated sulphuric acid, are firmly luted to the retorts, and the process continued until no more acid passes over. The acid thus obtained is a brownish-coloured, oily liquid, and was therefore formerly termed oil of vitriol. Exposed to the atmosphere, it evolves vapours of anhydrous sulphuric acid, and by this property, as well as by the power it possesses of dissolving indigo, it is distinguished from the



22.

hydrate. The fuming acid is also termed *Saxon* or *Nordhausen* sulphuric acid.

42. (2.) *Sulphurous Acid*, SO_2.—When sulphur is heated in the atmosphere it burns with a blue flame, and forms this pungent, suffocating, colourless gas, which slowly attracts oxygen from the air, and is thereby converted into sulphuric acid. If a sufficient quantity of sulphur be burned in a cask, the sulphurous acid formed removes the whole of the oxygen of the enclosed air, and consequently destroys its power of acidifying wine or beer that may be afterwards introduced into it. This process termed *sulphurizing*, or burning out of casks, is practised chiefly with the view of removing oxygen. Sulphurous acid is, moveover, employed as a remedial agent in various diseases of the skin, and for bleaching straw, wool, and feathers.

43. (3.) *Hydrosulphuric Acid*, HS.—This acid is a colourless, fetid-smelling gas, which is evolved on treating a metallic sulphide, such as sulphide of iron (FeS), with dilute sulphuric acid. It is, moreover, formed by the putrefaction of vegetable and animal matters containing sulphur, such as night-soil, &c., and may be easily recognised by its odour, which is abundantly evolved from rotten eggs. This gas is highly poisonous, and proves instantly fatal when breathed in the pure state. Many serious accidents have happened to workmen who have incautiously entered sewers and other places where animal matter is in a state of decomposition. In such cases the careful inhalation of chlorine, mixed with atmospheric air, has been found to produce very beneficial effects.

Hydrosulphuric acid is soluble in water, to which it imparts its properties, as is observed in the *sulphur springs* in which this fetid gas is contained. The deportment of hydrosulphuric acid towards the *heavy* metals and their oxides is highly important to the chemist, for when a current of this gas is passed into a solution of a metallic oxide, such as oxide of lead, the sulphur combines with the metal, producing an *insoluble* compound, which is immediately thrown down as a precipitate of *peculiar colour*.

This gas is capable of precipitating all the metals from their solutions, in the form of *sulphides*, and it furnishes us with a valuable means, not only of discovering the presence of metals in a liquid, but of effecting their complete separation.

COLOURS of METALLIC SULPHIDES.

	Black.	Brown.	Orange.	Flesh-colour.	Yellow.	White.
Sulphide of	Lead.	Copper.	Antimony.	Manganese.*	Arsenic.	Zinc.*
,,	Bismuth.	Tin (Proto-salts).			Tin.	
,,	Mercury.				Cadmium.	
,,	Silver.					
,,	Cobalt.*					
,,	Nickel.*					
,,	Gold.					
,,	Platinum.					
,,	Iron* (Fe S)					

The metals in the first column are mostly precipitated from *dilute* solutions of a *brown* colour, which, however, slowly passes into *black*; those marked *

are thrown down by hydrosulphuric acid from alkaline, the others from acid solutions.

The peculiar colour imparted to silver spoons used in eating eggs and fish, and the blackening of white-lead paint in stables, &c., is solely due to the formation of metallic sulphides.

9. PHOSPHORUS.

Symbol: P = 32 ; Specific Gravity = 1·75.

44. Although phosphorus is pretty generally diffused, and is everywhere met with in the soil, in the form of phosphates, it nevertheless occurs always in very small quantity, and hence belongs to the rarer elements. From the soil the phosphates are absorbed by many plants constituting the food of animals, and from which the phosphorus contained in the animal organism is derived. The animal body, indeed, forms, as it were, the store-house of phosphorus, for it is met with in eggs, in the brain, nerves, and flesh, and especially in the flesh of fishes. The greatest quantity, however, is contained in the bones, that consist of phosphate of lime (CaO,PO_5), from which the phosphorus of commerce is principally derived.

This element is invariably prepared from *phosphoric acid*, which is obtained by treating bones, burnt to whiteness (bone-ash), with sulphuric acid. The acid combines with the lime to form insoluble sulphate of lime (CaO,SO_3), and thus liberates the phosphoric acid which is concentrated by evaporation, mixed with pulverized charcoal, and ignited in an earthen retort. The carbon combines with the oxygen of the phosphoric acid, forming carbonic oxide, while the liberated phosphorus distils over, and is condensed in the receivers, which are filled with water.

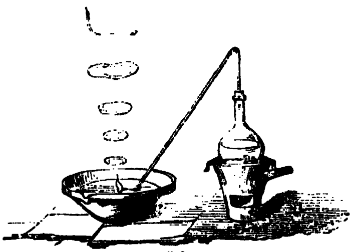
Phosphorus, when perfectly pure, is a colourless, transparent body, as soft as wax, and is easily cut with a knife. When exposed to the light it speedily acquires a yellow colour, and becomes opaque; in the air it evolves white vapours, which are luminous in the dark, and possess the odour of garlic. This luminosity appears to be due to oxidation, as the fumes emitted are found to consist of phosphorous acid (PO_3). At 35° C. (95° F.) phosphorus fuses; and at 70° C. (158° F.) inflames, with formation of anhydrous phosphoric acid, that appears as a snow-white powder which rapidly attracts moisture from the atmosphere, and is thereby liquified. The facility with which phosphorus inflames renders it a highly-dangerous body; the warmth of the hand, especially if accompanied by friction, being sufficient to ignite it. For this reason it is always preserved in vessels filled with water. Experiments made with phosphorus require the greatest precaution, the neglect of which has already occasioned many serious accidents.

But, on the other hand, the facility with which phosphorus ignites by slight friction renders it very suitable to the manufacture of the common *lucifer matches*, and its importance and preparation have been very much increased by the extensive consumption of the above-mentioned useful commodity.

The history of phosphorus is of remarkable interest, it having been accidentally discovered in 1669, by an alchemist of the name of Brandt, while engaged in the process of transmutation. On account of its scarcity, it was sold at first for its weight of gold, but at the present time the price has fallen to about three shillings per pound. The existence of manufactories in which

upwards of 100 lbs. of phosphorus are daily prepared, offers a remarkable proof of what improvement the manufacture is susceptible, whilst it incontestably shows that by the increased consumption the price has become proportionably diminished, and the quality of the preparation improved.

Of the compounds of phosphorus, we have already mentioned phosphorous acid (PO_3) and phosphoric acid (PO_5). The latter is a powerful, although not a caustic acid, and is employed in medicine both in the free state and in combination with soda.



23.

Phosphide of Hydrogen, PH_3.—This gas, commonly termed phosphoretted hydrogen is obtained by heating, in a flask (fig. 23), small fragments of phosphorus with milk of lime, or solution of caustic potassa. It possesses a disagreeable garlic-like odour, spontaneously inflames when brought into contact with atmospheric air, and produces most beautiful ringlets of smoke.

10. ARSENIC.

Symbol: As = 75 ; Specific Gravity = 5·7.

45. Arsenic has so many properties of the metals, that it appears to form the connecting link between the non-metallic and metallic elements, and is by many classed with the latter bodies. It generally presents a gray, metallic appearance, and possesses a considerable specific gravity. Hence we did not hesitate to classify it in § 43, with the metallic sulphides.

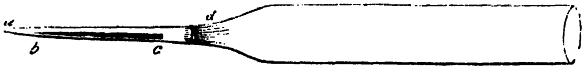
Arsenic is found partly native and partly in combination with sulphur, and with metals, such as iron, copper, nickel, and cobalt. Being a volatile substance, it is readily separated from the latter bodies by sublimation. (Phys. § 129.)

Compounds of Arsenic.

46. (1.) *Arsenious Acid.*—This compound is formed when arsenic is heated in a current of air. It is then evolved as a white vapour, of a strong *garlic* odour, and may be collected as a fine powder, which is usually termed *white arsenic*, or *arsenious acid.* It is odourless, tasteless, and in the highest degree poisonous. The latter property it is that unfortunately often leads to its employment for criminal purposes, cases of poisoning by this substance being by far the most common. They are in general characterized by vomiting and pains in the bowels, terminating in frightful convulsions and death. As a remedial means, the promotion of vomiting, on the first appearance of poisoning, is the most judicious treatment. A substance, however, has been discovered which has the property of immediately counteracting the effects of arsenic, viz., the hydrated sesquioxide of iron ($Fe_2O_3 + 3\,HO$), which forms a perfectly insoluble compound, that has no poisonous influence upon the system. This remedy has been already employed in many cases with the most happy results.

In judicial inquiries it is important to decide whether death has been occasioned by arsenic, and this can only be done by actually finding the poison,

and proving its presence beyond a doubt. By carefully searching the bowels and the ejected food, it is by no means difficult to discover the particles of arsenic, which, on account of their weight, are readily deposited. A particle as large as a needle-point is sufficient to show whether the poison met with is arsenic or not. For this purpose it is introduced into a glass tube (fig. 24),



24.

and covered by a small fragment of charcoal, *b c*, which is made red-hot, and the point of the tube then heated. If the substance under examination be actually arsenic, its oxygen will combine with the ignited charcoal, while a brilliant ring of the metallic element is deposited on the cool part of the tube, as seen at *d*. When the arsenic is no longer to be met with in the form of powder, it is more difficult to detect, but in such cases science has pointed out secure methods of proving its presence.

Notwithstanding its dangerous properties, arsenious acid is employed in many arts, as in the manufacture of glass, in dyeing, agriculture, for the destruction of obnoxious vermin, such as rats, &c., and in the preservation of wood.

(2.) *Sulphide of Arsenic.*—Arsenic combines in two proportions with sulphur. The *yellow* sulphide of arsenic, called *orpiment*, is found as a mineral, and is sometimes employed as a beautiful yellow pigment. The *red* variety, which is termed *realgar*, is obtained when sulphur and arsenic are fused together; it is employed as a colour in dyeing, and, in pyrotechny, as a component of the Bengal white-fire, which consists of 24 parts by weight of nitre, 2 of sulphur, and 7 of realgar, finely pulverized, dried, and intimately mixed together.

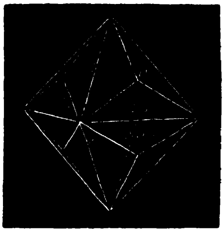
11. CARBON.

Symbol: C = 6.

47. This element, which usually occurs in a lustreless form, claims in many respects particular attention. On the one hand, the remarkable diversity of condition which carbon can assume, and the properties resulting from such assumptions; on the other hand, its relation to the animal and vegetable kingdoms, both in the free state and in combination, evince that carbon, next to oxygen, is the most important element in the economy of Nature. No substance furnishes us with a more remarkable confirmation of the principle enunciated in our chapter on Physics (§ 11), viz., that all matter is a conglomeration of smaller material particles, and that the properties of individual bodies are determined, not merely by the nature of these particles, but also by their *arrangement* or relative position. The variable forms of carbon, therefore, render it necessary to describe them individually; for the present it is enough to remark, that although crystallized carbon, vegetable carbon, animal carbon, and the various kinds of coals, exhibit a remarkable difference in their physical properties, they nevertheless so far agree as to allow us to designate carbon under all conditions a solid, tasteless and odourless, infusible and non-

volatile body, which is insoluble in every substance with the exception of fused cast-iron.

48. Crystallized carbon is known as diamond, and from the earliest times has attracted the attention of even the rudest nations by its extreme hardness and transparency, as well as by its extraordinary brilliancy, and its power of decomposing light into its prismatic colours. These characteristic properties, as also the rarity of its occurrence, have elevated it to the rank of the most costly of all the precious stones. Its specific gravity is greater than that of any other form of carbon, being equal to 4·0, its hardness superior to that of all other substances, and it can only be cut or abraded by a second portion of the same material. It is, moreover, brittle, and admits of being cleaved in certain directions. The crystalline form of the diamond is that of the regular octohedron, or some figure geometrically connected with these (figs. 25, 26, 27).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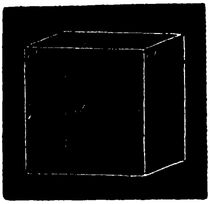
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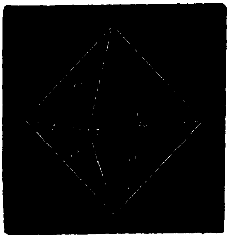

27.

The diamond is found in the alluvial soil of Golconda, in the West Indies, Peru, Brazil, and more recently in the Ural Mountains, and also in the drift-sand of their rivers.

With the conditions under which carbon crystallizes or the diamond forms, we are entirely unacquainted, and it is only barely probable that we shall ever be able to imitate these conditions, and produce diamonds artificially. It is possible that the vast masses of coal occurring in the laboratory of Nature have been exposed for many hundreds of years to an intense heat, of which we can hardly form a conception, and that the carbonaceous particles have, under such conditions, arranged themselves in a regularly crystalline form.

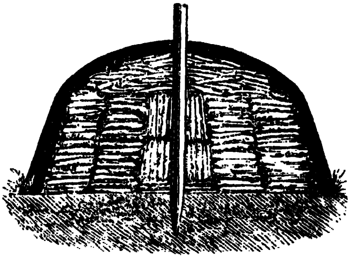
A long time elapsed before the identity of two apparently so dissimilar substances as charcoal and diamond was discovered. Accident, however, first led to the supposition, and in an experiment made with the view of fusing several small diamonds together, they were found to have entirely disappeared. A close investigation showed that they had been *burned*, or, in other words, had combined with oxygen to form carbonic acid (CO_2), a compound that is produced, of precisely the same properties, in the combustion of ordinary coal. If a diamond be heated in a closed vessel, with exclusion of air, it remains perfectly unaltered.

This precious stone is not merely used for ornamental purposes, but supplies us with a valuable means of cutting, or rather determining the fracture of glass, for which purpose its hardness renders it peculiarly adapted.

None of the other varieties of carbon are so free from foreign admixture as

the diamond, and hence we consider it as the purest condition under which this element occurs.

49. The origin of *vegetable* or *wood*-charcoal is indicated by the name. All substances of vegetable origin, without exception, contain carbon, which can be separated by a great variety of processes. Moreover, as carbon, oxygen, and hydrogen constitute the principal elements of plants, it follows that we may represent their composition by the general formula x (CHO). On burning wood, &c., with limited access of air, the two latter elements are expelled in the form of water, while a residue remains, consisting of carbon. This process is carried out on a large scale in the preparation of *wood-charcoal* from the denser kinds of wood, especially that of the beech-tree, which is arranged in piles, as in fig. 28. The wood is piled in horizontal layers, covered over with turf and mould, and kindled in the interior, small openings being here and there made for the purpose of admitting a little air. The whole mass slowly becomes ignited, but only the oxygen and hydrogen of the wood are expelled as products of combustion, while the unconsumed carbon remains. Notwithstanding all precautions, a considerable loss of carbon is experienced, varying in quantity according as the process is more or less complete. To avoid this loss, the carbonization is now frequently continued for a less space of time, and in this manner is obtained a variety which is distinguished as *red* or *brown charcoal*.



28.

We may assume that 100 parts by weight of wood dried in the air contain—

20	per cent	of water enclosed in its pores.
40	,,	oxygen and hydrogen.
40	,,	carbon.
100 parts, by weight, of wood.		

Accordingly, we have in 100 pounds of dried wood 80 of actual wood, and in the latter 40 pounds of carbon. But when the process is conducted most successfully it yields only about 25 pounds; in general not more than 20 pounds are obtained from 100 pounds of wood.

Wood-charcoal is exceedingly porous, and, consequently, its specific gravity is ordinarily very small. That of beech-wood charcoal is 0·187; a cubic foot, interstices included, weighing not more than from 8 to 9 pounds. It possesses in a high degree the power of attracting and condensing, within its pores, air, and aqueous vapour, which sometimes leads to its heating and spontaneous combustion. If impure water, containing hydrosulphuric acid and ammonia, be agitated with the powder of freshly-ignited charcoal, both gases are completely removed, and the water is rendered fit for the purposes of life. Wood-charcoal likewise removes colouring matters, but only to a slight degree, as will be described under animal-black.

Wood-charcoal is applied to a variety of technical processes, particularly to produce strong fires in a limited space. It is, moreover, of great importance

as a means of deoxidation, *i. e.*, of removing oxygen from metallic oxides, and combining with it to produce carbonic acid. Nearly all the metals, and particularly iron, are prepared by igniting their oxides in contact with carbon. Its use in the manufacture of gunpowder is likewise one of the most important of its applications.

At the ordinary temperature, carbon is only slightly affected by exposure to the atmosphere, and is almost unaltered when placed either in water or in the soil. We advantageously avail ourselves of this property by charring the ends of piles that are to be driven into the earth, and likewise by carbonizing the interior of casks in which water is preserved during long sea-voyages. *Soot* is a vegetable carbon in a finely-pulverized state, and is employed in the preparation of a fine black colour known as Indian ink. To obtain the particular kind of carbon used for this purpose, resin, resinous woods, and such-like substances, are burned with imperfect access of air, and the smoke evolved passed into a hood in which the soot is deposited. The variety known as *Frankfort-black*, or *Printers'-black*, is obtained, in a very finely-divided state, by the carbonization of wine-yeast; it is mixed, however, with salts of potassa.

The varieties of vegetable carbon here decribed are by no means to be considered as pure, as may be readily proved by the quantity of ash they yield when burned. The charcoal from 100 pounds of wood will of course contain the same amount of ash as would have been obtained in the combustion of the wood itself. One hundred pounds of beech-wood is found to yield about 0·03 pound of ash; on the other hand, lamp-black which has been thoroughly ignited appears to be almost chemically pure carbon.

50. The black mass which is left on charring animal substances is termed *animal carbon*: it differs very considerably from the foregoing, in its physical as well as chemical properties. Independently of animal fat, which is in all respects analogous to the fatty substances found in plants, we include under the general title of animal products muscular flesh, the skin (leather), cartilage, osseous gelatin, and blood. We refer, moreover, to these substances in the dry or anhydrous condition. Their principal mass in the dry state consists approximately of—

55	parts, by weight,	of carbon.
22	,,	oxygen.
7	,,	hydrogen.
16	,,	nitrogen.
100	parts, by weight,	of animal matter.

They contain besides a minute quantity of phosphorus, sulphur, and inorganic salts. When heated, these substances first swell up and fuse, then cake together, and finally yield a dense, slaggy, lustrous charcoal. This, of course, is not to be considered as pure carbon, for, in addition to phosphates and sulphates, it contains a considerable quantity of nitrogen, so that we may with propriety term it *nitrogenous* carbon. The presence of this element renders it well adapted for the preparation of the chemical compound which forms the basis of the manufacture of Prussian blue, and will be described farther on, under the name of cyanogen.

51. *Bone-charcoal*, termed also bone- and ivory-black, is an animal carbon, which is obtained by burning bones imperfectly. We must regard a bone in its entire mass as a structure consisting of two cellular substances interwoven

with each other, as may be represented by figs. 29, 30, and 31, where *a a* represent a soft texture termed gelatin, whilst *b b* are particles of a hard texture which is incombustible, and consists of phosphate of lime. When bones are ignited with free access of air, the gelatinous particles *a a* are *completely* consumed, and there remains only a white, dense, calcareous tissue (fig. 31), which is bone-ash. If, on the other hand, a bone is digested in hydrochloric acid, the lime-salts only are dissolved, while the gelatin is unattacked, and remains as represented in fig. 30. When the gelatin, extracted by hydrochloric acid, is carbonized by itself, the carbonaceous particles cake together, and we obtain a compact carbon, differing in no respect from the nitrogenous variety above described. If, on the other hand, the gelatin of the bones is carbonized by ignition with a limited supply of air, the calcareous particles prevent the cohesion of the carbon, and we obtain from the bones thus burned an animal-black in a very finely-divided state.

29. 30. 31.

Bone-charcoal is particularly distinguished by its power of combining with dissolved colouring matters and removing them completely from their solutions. If red wine or red ink be agitated with a few spoonfuls of bone-carbon, we obtain, after some time, a transparent liquid as colourless as water. This property is of considerable advantage in the manufacture of sugar; for, when the brown-coloured cane-juice is treated with bone-black, it is rendered perfectly colourless, and a brilliant white sugar is thus obtained. Many other chemical preparations may, by this means, be likewise decolorized, or deprived of the colouring matters which are mixed with them.

Bone-black, as is well known, is also used in the manufacture of blacking, which is usually prepared by mixing four parts with one of sulphuric acid, and then adding four parts of syrup and a little water.

52. *Graphite*, termed also black-lead, is a mineral belonging to the primitive rocks, and occasionally consists of pure carbon; in general, however, it contains a portion of iron. It may be also artificially prepared by the fusion of iron in the smelting furnaces of iron-works. It possesses a grayish-black colour and metallic lustre, and produces a mark when rubbed on paper; a property on which depends its application to the manufacture of lead-pencils. *Anthracite*, a less pure form of carbon, is more allied to coal, and, when burned, leaves an earthy ash. Both varieties will be more minutely described in the chapter on Mineralogy.

Coal and turf are carbonaceous formations, derived from the spontaneous decomposition of plants. The origin of these substances will be considered hereafter.

Compounds of Carbon.

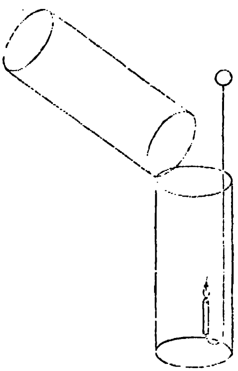
53. Carbon combines with oxygen in several proportions.

Carbonic acid (CO_2) is a colourless, odourless gas, which is contained in the atmosphere in the proportion of 1 measure to 2,500 measures of air. It occurs, moreover, in many minerals, combined with metallic oxides, particularly with lime, forming a compound of which entire ranges of hills are composed.

This acid is produced incessantly by the combustion and decay of carbonaceous substances, and by the process of fermentation and the respiration of animals. Its quantity would, therefore, be continually on the increase, were it not that plants remove it from the atmosphere, and thus preserve the equilibrium in a very remarkable manner. We shall still have occasion in a subsequent section to point out with greater precision the important relation existing between carbon and the animal and vegetable kingdoms.

In the preparation of carbonic acid we may avail ourselves most conveniently of carbonate of lime or chalk (CaO,CO_2), which is decomposed by either of the stronger acids, generally by hydrochloric acid. The carbonic acid is set free and evolved in bubbles, producing a lively effervescence, which is the characteristic deportment of all carbonic acid compounds when treated with a strong acid.

If a burning taper be immersed in a vessel filled with carbonic acid, it is immediately extinguished, and men and animals that inhale the pure gas die almost as suddenly; it is therefore to be considered as a highly-dangerous poison when inhaled. The specific gravity of this gas being 1·5, or half as heavy again as air, it will sink in this medium precisely in the same manner as syrup will fall to the bottom of a vessel of water, and mix with the latter fluid only very gradually. If therefore a lighted taper be placed on the bottom of a cylinder (fig. 32), and carbonic acid be slowly poured into it from a vessel filled with this gas, the light will be extinguished immediately the gas reaches to the height of the flame. In cellars where large quantities of wine and beer ferment, the lower stratum of air invariably consists of almost pure carbonic acid, and it not unfrequently happens that workmen lose their lives by stooping down and incautiously inhaling the gas. To obviate this danger, it is usual either to insure a sufficient change of atmosphere, or to mix up caustic lime with water, and sprinkle about the milky liquid, which speedily removes the carbonic acid from the floor. For those who have been suffocated by carbonic acid, the careful inhalation or smelling of ammonia has been recommended as the most efficacious antidote.



32.

From the lower strata of earth, where, in many places, carbonaceous substances are continually undergoing decomposition, streams of carbonic acid gush forth in a manner similar to springs of water; and if holes of some depth be dug, particularly in volcanic districts, the carbonic acid is heard to rush in with considerable noise: hence it frequently collects at the bottoms of wells and mines, and there causes fatal accidents. In the neighbourhood of Naples there is a cave, termed the Grotto del Carne, in which occurs a stratum of carbonic acid, several feet in height, issuing from the soil. Dogs and other animals die immediately they are placed in it, whilst men may walk erect therein without danger. In Java there is a valley called the Poison-valley, or the vale of death, surrounded by a chain of mountains. The air of this valley contains so

large an amount of carbonic acid that men and animals who enter it never return alive.

Carbonic acid is soluble in water, and imparts to it an agreeably-refreshing and slightly-acid taste: nearly all waters occurring in Nature contain a portion of this gas in solution. Whenever springs of water and carbonic acid come in contact in the earth, a large quantity of gas is dissolved, and the water then receives the name of *acidulous* water, such as Selters' water, and many others. Carbonic acid, moreover, is contained in many liquids that are derived from fermentation, as new wine, beer, and champagne; and as the internal use of these liquids is within certain bounds uninjurious, it would appear that carbonic acid has no poisonons action on the stomach, but only exerts its pernicious influence when taken into the lungs.

When carbonic acid is compressed in a suitable apparatus, it is converted into a liquid, which, on removal of the pressure, evaporates with extreme rapidity, absorbing so much heat (Phys. § 146) that a cold is produced of $-80°$ C. or $-90°$ C. (about $-180°$ F.), a portion of the liquid acid being thereby frozen. Carbonic acid, therefore, affords an important example of the principle, enunciated in the chapter on Physics, that the condition of matter is essentially dependent upon temperature.

Carbonic acid is extensively employed in the manufacture of white-lead and of the artificial effervescing drinks.

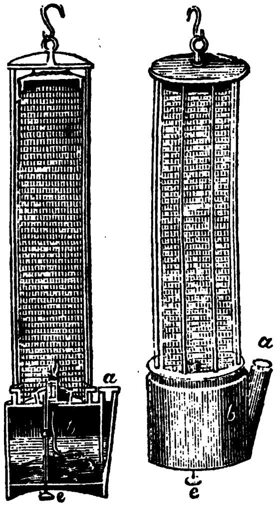
Carbonic oxide (CO) is the name applied to the lowest product of the oxidation of carbon, which is formed when this element is ignited, with limited access of atmospheric air. This gas burns with a beautiful blue flame, as frequently observed in charcoal fires, and gives rise to the formation of carbonic acid. It is likewise irrespirable, and, in conjunction with its product of combustion, is the cause of the fatal accidents which sometimes occur when charcoal is burned in closed rooms.

Carbides of Hydrogen.

54. In all cases where vegetable matter, which we always represent by the general formula x(CHO), (§ 49), suffers decomposition, a portion of the carbon combines with hydrogen, and produces gaseous compounds. If the vegetable matter contains a large quantity of carbon, as is the case in resins, fats, &c., and the decomposition takes place under a high temperature, the carbo-hydrogen = CH is produced, which burns with a highly-luminous flame, and is hence termed *illuminating* gas. But if the decomposition of the vegetable matter is effected at a lower temperature, as, for instance, when the remains of plants decay in marshes or at the bottoms of mines, there is formed an inferior carbide of hydrogen = CH_2, which is therefore termed *marsh-gas*, or the gas of mines.

Marsh-gas, whenpure, is colourless and odourless, and burns with a slightly-luminous flame. Its specific gravity is 0·5. When mixed with atmospheric air and then kindled, an explosion takes place similar to that which is produced by the ignition of explosive gas (§ 28). In coal-mines an enormous quantity of this gas is continually generated; it there becomes mixed with the air of the mines, and causes frightful explosions when accidentally kindled by the lights of the workmen. A large number of miners have already lost their lives by this gas, which is technically called *fire-damp*. The numerous

fatal accidents have led to the discovery of the *safety-lamp* (fig. 33), an instrument consisting of an ordinary oil-lamp surrounded by fine wire-gauze. If a lamp of this kind is introduced into a mixture of explosive gas, the gas enters by the openings of the gauze, and burns in the interior; the flame, however, is so much reduced in temperature, by the cooling influence of the metallic wire, as to become extinguished before it is communicated to the external gas. This cooling power of wire-gauze may easily be demonstrated by holding it over the flame of a candle, which will be found not to pass through.



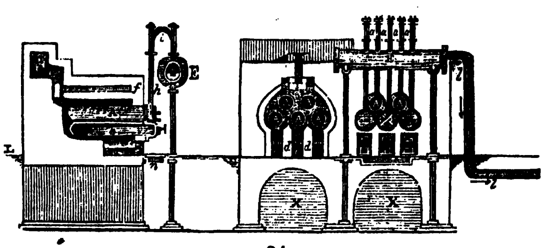
33.

The gas of mines is one of the constituents of the ordinary coal-gas which is employed in illumination and in filling balloons.

55. The *luminous gas* (CH) is obtained when bodies rich in carbon and hydrogen, and deficient in oxygen, are ignited in closed vessels. It is a colourless gas, burning with a beautifully-luminous flame, and is the chief component of all our artificial means of illumination. It is either consumed at the spot and in the moment of its formation, as is the case in the burning of candles and lamps, or it is collected in a peculiar vessel, termed a *gasometer*, and thence distributed by iron pipes to our streets and houses.

The preparation of luminous gas is most simply effected by dropping fats or resins into red-hot iron cylinders, and for this purpose are selected the cheapest varieties, which can scarcely be used for other purposes. These substances are decomposed, and yield a gaseous mixture that burns with a remarkably beautiful and bright luminous flame: this mode of manufacture, however, appears not to admit of general adoption in consequence of the high price of the materials, but when coals are employed, as is generally the case in this country, the price of production is considerably diminished.

56. The manufacture of coal-gas is divided into three processes, viz., its *formation*, *purification*, and its *collection* and distribution. Its formation is always effected in longish round retort-cylinders of iron, arranged in the manner shown by A A A A A in fig. 34. The first part of the figure represents a section of a furnace, and the second a front view of two furnaces.

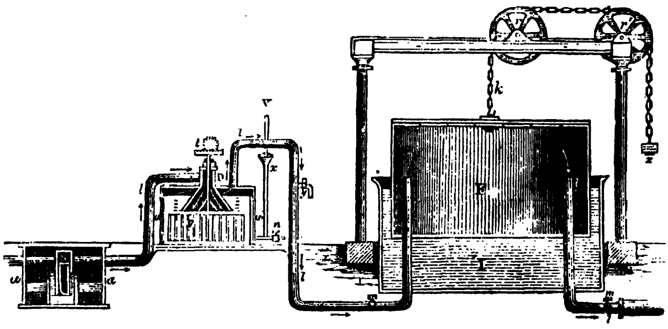


34.

The fire is placed around the retorts upon the grate *c c c*. The ash-pit is at *o o o*. The whole apparatus is so arranged that the greatest degree of heat may be produced at the least expense of fuel. The cylinders are closed at the posterior end, and open in front, being each provided with a door which is made to fit air-tight by means of screws and cement. In these cylinders the coal is distilled, and as soon as the evolution of gas has ceased, the doors are opened and the glowing coke raked out and allowed to cool in the vaults *x x*.

The gas as it issues from the cylinders passes through the iron pipes *h i* into the hydraulic main E, which is half filled with water. The pipes *i i* dip below the surface of the water in order to prevent the gas returning into the retorts when the doors are opened.

In the hydraulic main a considerable quantity of matter volatilized with the gas is deposited. From the upper part of the main passes a pipe, *l*, which first descends into the ground, and then runs in a horizontal direction. Through this pipe the gas escapes. At the lowest part of this horizontal pipe there is another descending-pipe which is open at the bottom, and dips into a cylindrical vessel, encompassed by a third vessel, as shown at S in fig. 35.



35.

The liquid deposited in the hydraulic main E, during the distillation, continually runs over with the gas by the pipe *l*, and enters the condenser by the pipe S. It there fills the surrounding cylinder, and afterwards runs over into the vessel it is placed in, from which it can be removed at pleasure.

Thence the gas pursues its course through the pipe *l* and arrives at the purifying apparatus D. This consists of a large cylindrical vessel, made perfectly air-tight, and having an inverted funnel fixed in its top. A rod passes through the neck of the funnel, and by means of a winch and toothed wheel, *t*, is made to revolve. The bottom of the rod is connected either with a wheel or frame of cross-bars *g*. The vessel D is two-thirds filled with a mixture of lime and water, which is introduced by the pipe V. The gas passes by the pipe *l* into the funnel, presses down the lime-water to the edge of the funnel, and then escapes in bubbles through the surrounding liquid. The gas is thus freed from sulphuretted hydrogen and carbonic acid: when it appears necessary to renew the purifying mixture, it is allowed to run out by the cock *n*, and a fresh portion introduced by the tube V *x*.

As the gas escapes from the purifier by depressing the liquid in the funnel,

it is necessarily in a condensed state in the pipe between the vessel and the retorts; the extent of the pressure is equal to the weight of the water that stands higher on the exterior than in the interior of the funnel. Hence the liquid in the pipe S is not so high as that in the surrounding vessel; it is therefore necessary that the pipes from the hydraulic main E to the retorts should be raised as shown at *i* and *a a a a*, otherwise upon opening a retort the liquid in the hydraulic main E would be forced back through the pipes *i h*.

We have thus traced the progress of the gas from the retorts wherein it is produced to the purifier in which it is deprived of its impurities; we have next to consider the mode of collecting and distributing it. The gasometer F, fig. 35, which is sometimes as much as 30 or 40 feet in diameter, is a cylinder of iron closed at the top, open at the bottom, and dipping into a second vessel filled nearly to the edge with water. The gas-holder is supported by a chain, *k*, which passes over the two wheels *r r'*, and is counterbalanced by the weight, *z*. At the commencement of the operation, the cock *m* is closed, and that leading from the purifier is opened, the gas-holder being previously depressed to the bottom of the vessel I. As the gas enters, the gas-holder rises in the water until perfectly filled with gas.

When the gas is to be distributed, the cock *m* is opened, and the gas-holder depressed by means of suitable weights placed on the top. The gas then flows through the pipe *l*, whence it is distributed to its destined place of consumption.

57. Coal-gas is always a mixture of luminous gas (more commonly called olefiant gas), marsh-gas, carbonic oxide, and hydrogen, in variable proportions, depending upon the nature of the coal and of the process of manufacture. In the beginning of the distillation, the olefiant gas, which, of course, is the most valuable constituent, forms approximatively one-fifth of the entire volume, but towards the end of the process, or by too strong a red-heat, its quantity considerably diminishes, while that of the hydrogen increases. We may consider that an ordinary gas-flame hourly consumes from 1 to 1½ cubic feet of gas. From one pound of coal we obtain from 5 to 6 cubic feet of gas, and coals of the best quality sometimes yield from 7 to 9 cubic feet; while from one measure of oil we obtain from 600 to 700 measures, and from 1 lb. of resin from 14 to 23 measures of gas are produced.

In the retorts remain the *coke* which is employed as a very excellent fuel.

Finally, it may be remarked that coal-gas is employed, in the place of hydrogen, for filling balloons. A ball of three feet diameter filled with the former weighs 11 ozs. less than one containing an equal volume of air, while, if filled with hydrogen, it weighs about 17 ozs. less; the cost of hydrogen, however, is 20 times as much as that of coal-gas.

58. In addition to the two carbo-hydrogens here described, a large number of chemical compounds are known, which consist only of these two elements. They form, however, more compound groups, and will therefore be considered in another part of this section.

Bicarbide of Nitrogen (Cyanogen).

59. Carbon combines only with difficulty and under particular circumstances with nitrogen. When the nitrogenous carbon, described at § 50,

is ignited in contact with a metal, the two elements combine together, producing a new substance, termed *cyanogen* (C_2N), which enters into combination with the metal. When a compound of mercury and cyanogen (Hg Cy) is heated, the latter is obtained as a colourless gas, of penetrating odour. When kindled it burns with a beautiful peach-coloured flame. In its mode of combination, this body presents such a remarkable similarity to chlorine, bromine, iodine, and fluorine, as to have induced chemists to class it with these elements: its formula instead of being expressed by C_2N is usually represented by the symbol Cy. The name cyanogen signifies to generate blue, and this compound was so called in consequence of its forming with iron the beautiful blue pigment, known as ***Prussian blue.*** Cyanogen combines with hydrogen and produces hydrocyanic or prussic acid (H Cy), which is prepared by the distillation of cyanide of mercury with hydrochloric acid.

$$HgCy + HCl = HCy + HgCl.$$

This acid is a colourless gas, of a peculiar odour, strongly resembling that of bitter almonds; it is soluble in water, and imparts to it its properties. Particularly in the anhydrous state it forms a deadly poison, but when diluted with water it is extensively employed as a remedial agent. The kernels of stone-fruit, and especially those of the bitter almond, as well as the leaves of the cherry-laurel, which contain a small quantity of prussic acid, are likewise employed in medicine as well as in confectionary, and in the preparation of laurel-water.

Bisulphide of Carbon.

60. When wood-charcoal is heated to redness in a tube of iron or earthenware, and sulphur is introduced through an opening in the tube, the vapour of the latter in passing over the carbon combines to produce a volatile substance which is condensed in an apparatus (Phys. § 129, fig. 89) connected with the tube. This compound, which is a colourless transparent liquid, is termed *bisulphide of carbon*, and offers one of the most remarkable examples of the destruction of the peculiarities of elements by chemical combination. From the *solid* yellow sulphur that combines with the *solid* black charcoal, we obtain a *liquid* transparent body of extreme volatility and disagreeable odour. It refracts light so powerfully, that on looking through a vessel containing it, we observe the most beautiful prismatic colours. Bisulphide of carbon is heavier than water, and dissolves with facility sulphur, phosphorus, and several resins, but is scarcely ever employed.

12. SILICIUM.

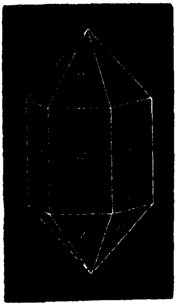
Symbol: $Si = 21 \cdot 3$.

61. Silicium never occurs in the free state, but in combination with oxygen, as *silicic acid* (SiO_3), which is the principal constituent of most minerals. Next to oxygen, silicium may be said to constitute the chief mass of the crust of our earth.

When separated from its oxygen, silicium forms a grayish-brown powder, which is non-volatile, and when heated in an atmosphere of oxygen combines again to produce silicic acid of snowy whiteness.

In the consideration of the compound *silicic acid* (SiO_3), we have to distinguish it under several conditions and in various states of purity.

Rock crystal which is frequently found in the caverns of St. Gothard, crystallized in beautiful six-sided prisms, terminating in pyramids with six faces (fig. 36), is pure silicic acid. White *quartz* is nearly pure silicic acid, containing scarcely a trace of foreign matter, whilst flint, agate, carnelian, jasper, and many other precious stones with which we shall become acquainted in the section on Mineralogy, contain a considerable quantity of other substances. These minerals are distinguished by the hardness peculiar to silicic acid, which imparts to them the property of emitting brilliant sparks when struck with steel. Silicic acid is fusible only in the strongest fires, but when heated to redness with the oxides of the light metals, it combines to produce a series of important compounds, such as glass. porcelain, earthenware, &c.



36.

If silicic acid be heated to redness with an excess of caustic alkali, as potassa, soda, or lime, it combines to produce salts which are soluble in water, and from which the weak silicic acid may again be separated in the form of a white gelatinous mass, by the addition of a stronger acid. The liberated acid is soluble in pure water, but loses this property when ignited.

In this soluble form, silicic acid is contained in almost all springs, whence it enters into the organisms of plants, being as essential to their nourishment as salt is to animals. Most plants, particularly the grasses, contain so large a quantity of silicic acid that it may readily be detected in the ash after they are burned. Moreover, the property of cutting, possessed by many grasses (carex, for example), depends upon the accumulation of small hard crystals of silicic acid in the cells of their leaves. It may also be remarked, that the shells or scales of many infusoria, as well as of some of the molluscs and polypi, consist of silicic acid.

Silicic acid is not acid to the taste, and is endowed with very feeble affinity; hence it is sometimes designated by the term *silica.*

13. BORON.

Symbol: Bo = 10·9.

62. Boron belongs to the rarer elements, being found only in some lakes of volcanic origin, in combination with oxygen, as boracic acid (BoO_3). In the free state it forms a brownish-green, insoluble, and infusible powder; so that both silicium and boron offer, in reference to their external properties, some points of agreement with ordinary carbon.

Boracic acid is deposited from the water of those volcanic districts in the form of a white powder, and, when purified, is obtained in colourless crystalline plates, which are soluble in alcohol, and to the flame of which the acid imparts a beautiful *green* colour; a property which is frequently made available in coloured illuminations.

A compound of boracic acid with soda ($NaO,2BoO_3$), termed *borax*, is frequently employed, since it may be fused for a long period at a high temperature, and without being altered in its properties. In fusing metals it

is frequently added with the view of facilitating the union of the metallic particles, and partly to protect them from the oxidizing influence of the atmosphere. An impure variety of borax occurs as a mineral, and is known under the name of *tinkal.*

(2.) METALS.

63. The metals, with the exception of mercury, are solid bodies, which, however, *melt*, or assume the liquid form, at high temperatures, and, when exposed to a still more intense heat, are converted into vapour. The clean and polished surfaces of metals reflect light and have considerable lustre, which is termed the *metallic lustre.* The greater number possess a high specific gravity, and their particles exhibit a very powerful cohesion, which renders them ductile and malleable, and allows of their being drawn out into wires. They are excellent conductors of electricity.

The metals possess a remarkable affinity for oxygen, and by far the greater number occur in Nature combined with this element. The metallic oxides, contrary to the oxides of the non-metallic bodies, are pre-eminently compounds with *basic* properties. A very limited number of the higher metallic oxides have the characters of acids, and are therefore termed *metallic* acids (§ 23). Their affinities for bases, however, are much less powerful than those of the strong acids of sulphur, nitrogen, and phosphorus, and also of hydrochloric acid. Most of the metallic oxides are insoluble in water.

The metals combine readily with *chlorine*, producing *neutral* compounds, which are termed *chlorides*, and possess the properties of the salts that are formed by the union of metallic oxides with oxygen-acids. The chlorides are mostly soluble in water, and are proportionately seldom met with in Nature. The elements *iodine*, *bromine*, *fluorine*, and the compound radical *cyanogen* (§ 59), exhibit an analogous deportment towards the metals, and, owing to their faculty of producing with the metals saline compounds, they are called *salt-formers* (haloids), and their salts, *haloid-salts*, in contradistinction to the oxygen-salts, or salts of the metallic oxides.

Next to oxygen, sulphur is the element with which the metals are most frequently found in combination. Its natural compounds with the heavy metals have a metallic and, usually, brass-yellow appearance; while those which are artificially prepared are powders of various colours (see § 43). The combinations of sulphur with the metals are termed *sulphides*, and generally have strongly *basic* properties. Some of the higher sulphides, however, deport themselves as acids, and unite with the inferior combinations to form peculiar *sulphur salts*. The sulphides exhibit so powerful an affinity for oxygen that many absorb it even in the air or in water, and become transformed into sulphates of the metallic oxides, whilst others combine with oxygen only when exposed to a high temperature. When treated with an acid, the sulphides yield hydrosulphuric acid and a salt of the oxide.

Classification of the Metals.

64. The metals admit of being readily distinguished by the following table, in which they are presented in several groups, according to their peculiar properties, and each distinguished by a particular name:—

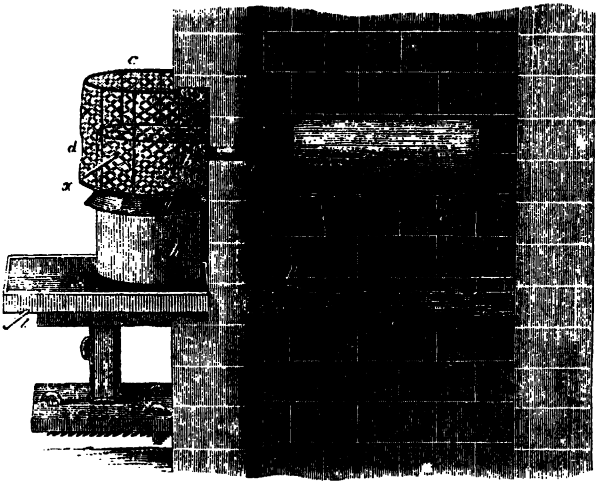
Metals.	Properties of the Oxides.	Properties of the Sulphides.
(A.) *Light Metals.* Specific gravity from 0·8 to 1 never occur in the uncombined state.	Powerful bases; possessing a strong affinity for water, and form with it hydrates. They yield their oxygen to carbon only at a white heat.	Powerful bases, which oxidise in the air, and form sulphates; when treated with acids evolve hydrosulphuric acid.
(a.) *Alkaline Metals.* 1. Potassium. 2. Sodium. (Ammonium.)	Highly caustic; powerful bases, separate all other oxides from their combinations with acids; are very soluble in water, and do not lose their water of hydration at the highest temperatures; attract carbonic acid rapidly from the air.	Caustic; strong bases; very soluble in water, and dissolve a large quantity of sulphur, which is separated on addition of an acid as a white powder, termed *milk of sulphur;* they were formerly termed *liver of sulphur.*
(b.) *Metals of the Alkaline Earths.* 3. Calcium. 4. Barium. 5. Strontium.	Caustic; strong bases; slightly soluble in water; lose their water of hydration at a moderate heat, and powerfully absorb carbonic acid.	Caustic; strong bases; dissolve sulphur, and are partly soluble in water, and partly insoluble.
(c.) *Metals of the Earths proper.* 6. Magnesium. 7. Aluminum.	Feebly caustic. Not caustic. } Weak bases, insoluble in water.	Insoluble in water.
(B.) *Heavy Metals.* Specific gravity from 5 to 21; are found chiefly in combination with oxygen, and frequently with sulphur and arsenic; some are native.	Feebler bases than the foregoing, some are acids; insoluble in water, and lose their water of hydration at a moderate heat.	Neutral compounds; insoluble in water; antimony and several of the rarer metals produce compounds with sulphur, which deport themselves as acids.
(a.) *Common Metals.* Become oxidised in the air. 8. Iron. 9. Manganese. 10. Cobalt. 11. Nickel. 12. Copper. 13. Bismuth. 14. Lead. 15. Tin. 16. Zinc. 17. Chromium. 18. Antimony.	With few exceptions are soluble in acids, and, when ignited with carbon at a red-heat, yield their oxygen; are, for the most part, fusible and non-volatile.	Those occurring in Nature are somewhat brass-like in appearance, and are termed *pyrites* and *blendes.* Those which are artificially prepared have peculiar colours, as mentioned at § 43; by heat they are converted into sulphates.
(b.) *Noble Metals.* Unchangeable in the air. 19. Mercury. 20. Silver. 21. Gold. 22. Platinum.	Have more the properties of acids than of bases; are decomposed by ignition into oxygen and metal.	With the exception of sulphide of mercury, they leave the pure metal when ignited.

(A.) LIGHT METALS.

14. POTASSIUM.

Symbol: K = 39 ; Specific Gravity = 0·8.

65. When carbonate of potassa (KO,CO_2) and charcoal, finely pulverized and mixed, are exposed to a white heat in an iron retort *a*, fig. 37, the oxygen



37.

of the potassa combines with the carbon whilst the potassium is volatilized as a greenish vapour. The vapour condenses in the form of metallic globules of the size of peas in the copper receiver *h*, which is half-filled with mineral *naphtha*. To facilitate the condensation of the potassium, the receiver is surrounded by a wire basket *b x c d*, filled with ice. Although the materials employed in the preparation of this element are by no means costly, it nevertheless retains its high price, owing to the difficulties of the operation and the small quantity obtained.

Potassium exhibits the lustre of silver, and is sufficiently soft to admit of being cut with a knife. Its most remarkable property, however, is the powerful affinity it possesses for oxygen; for, when exposed to the air, it immediately attracts this gas, and becomes covered with a gray coating of oxide of potassium. It abstracts oxygen with the greatest avidity from all bodies containing it, and therefore it can only be retained in the metallic state by preserving it in mineral naphtha, which consists only of carbon and hydrogen.

One of the most beautiful chemical experiments may be made by throwing a fragment of potassium upon water contained in a plate. The metallic globule immediately combines with the oxygen and developes a temperature sufficiently high to inflame the evolved hydrogen, to which the vapour of the burning potassium, simultaneously liberated, imparts a beautiful violet-colour

The burning metal floats about with a hissing noise upon the surface of the water until it is entirely converted into oxide of potassium, which dissolves in the water.

Hitherto, potassium has received no application in the arts, although the chemist avails himself of its powerful affinity in separating oxygen from many other oxides, such as silicic acid, boracic acid, magnesia, &c.

Compounds of Potassium.

66. *Oxide of potassium* (KO), usually termed potassa, is obtained in the form of hydrate (KO,HO) when the carbonate of potassa is boiled with caustic lime until it has lost the whole of its carbonic acid (§ 79), which may be readily ascertained by the non-effervescence of a filtered portion of the liquid on addition of hydrochloric acid. The solution, after it has become clear by standing, is evaporated to dryness and ignited, when the dry *hydrate of potassa* is obtained in the form of a white hard mass, which is commonly called *caustic* potassa.

Solution of potassa is in the highest degree alkaline (§ 17) and caustic. It dissolves all vegetable and animal substances, particularly fats, and is therefore to be considered as a highly-dangerous substance. Moreover, as it attacks all vessels of which silicic acid is a constituent, it is necessary to employ either iron or silver vessels in all operations in which it is fused, and likewise in its preparation.

Hydrate of potassa is employed in medicine as a caustic; its solution is used in the *manufacture of soap*, and, in a very diluted state, for the purpose of washing. Exposed to the air it rapidly attracts carbonic acid, being slowly converted into carbonate, whereby it loses its caustic properties.

67. *Sulphide of potassium*, which claims our particular attention, is the pentasulphide (KS_5) which is formed when a pulverized mixture of carbonate of potassa and sulphur is gently heated. We thus obtain a fused mass of a fine liver-colour, which is termed *liver of sulphur*, and is almost as alkaline as caustic potassa. The solution of sulphide of potassium is yellow, and evolves hydrosulphuric acid on addition of an acid, a portion of sulphur being at the same time deposited as a very fine white precipitate, which is termed *milk of sulphur*. When exposed to the influence of the atmosphere it rapidly attracts oxygen and moisture, and is converted into sulphate of potassa. The sulphide of potassium is employed in medicine, particularly for sulphur baths, and in chemistry as a means of deoxidation. Its solution is capable of dissolving a considerable quantity of sulphur.

68. *Carbonate of potassa* (KO,CO_2) is the compound of potassium, from which all the others are prepared. It is obtained by exhausting wood-ashes with hot water, evaporating the brown liquid to dryness, and igniting the residue. The gray mass thus obtained is commonly known by the name of *potashes*; it contains in admixture a variety of other salts.

Carbonate of potassa has a mild, alkaline taste, and communicates a blue colour to reddened litmus-paper; the carbonic acid being insufficient to neutralize the highly-basic properties of the potassa. From the atmosphere it absorbs moisture with avidity, and is ultimately liquified.

The ashes of different plants afford very dissimilar quantities of potashes;

1,000 lbs. of different vegetable substances have been found to yield as follows: pine-wood, 0·45 lb.; beech-wood, 1·45 lb.; oak-bark, 4 lbs.; straw, 5 lbs.; beech-bark, 6 lbs.; the bean-plant, 20 lbs,; nettles, 25 lbs.; thistles, 35 lbs.; and wormwood, 93 lbs. of potashes. Manufactories of this important substance exist in the woody districts of Germany and Russia, and particularly in the immense forests of America.

Potashes are employed in the preparation of all the other compounds of potassa, and particularly of alum, soap, and glass.

69. A most important salt of potassa is the *nitrate*, (KO,NO_5), which is commonly known under the name of *saltpetre*. In the formation of this compound the requisite quantity of nitric acid is produced by the decomposition of nitrogenous organic compounds. As we have seen at § 33, oxygen and nitrogen combine together to produce nitric acid, only under particular circumstances. This formation takes place principally when nitrogenous animal matters are suffered to decay in contact with metallic oxides; the nitric acid produced combines with the oxides, as is observed particularly in stables and in the neighbourhood of dung-heaps, where animal substances suffer decomposition. Walls are frequently observed to be coated with small crystals of nitre, possessing a bitterish cooling taste. When animal matters, manure, &c., are intentionally heaped together with moist earth, containing lime and potassa, we have all the conditions required for the formation of saltpetre. The saltpetre beds are exhausted with hot water, and the salt purified by repeated crystallization, when it is obtained in beautiful six-sided columns. The manufacture of saltpetre has considerably diminished since the discovery, in Chili, of large natural beds of nitrate of soda (NaO,NO_5), which is known in commerce as *Chili saltpetre*, and admits of being employed in many cases instead of the ordinary compound of potassa.

Saltpetre has a cooling, saline taste, and is frequently used as a remedial agent, and in the preparation of nitric acid. Exposed to a high temperature, it fuses, and if combustible substances be then brought in contact with it they combine with its abundant store of oxygen, and burn with brilliant vivacity. On this property depends the important application of saltpetre to the manufacture of gunpowder.

Gunpowder is a mixture of 76 parts of saltpetre, 11 of sulphur, and 13 of carbon, separately ground, and mixed into a paste with water. The mass is then compressed by a sieve, to obtain it in small grains, which are afterwards polished by revolving them in a vessel with pulverized charcoal. The manner in which gunpowder acts is readily explained: it is a solid body, decomposing at the moment of inflammation into several gaseous compounds, which are enormously expanded by the heat produced, and are thereby capable of overcoming the most powerful resistance and of producing very formidable effects. From the *solid* gunpowder, which may be represented by the formula $KO, NO_5 + C + S$, are formed by combustion nitrogen, carbonic oxide, and sulphurous acid $= N + CO + SO_2$, all of which are *gaseous* bodies, whilst potassa (KO), in combination with sulphurous acid, remains behind; or, if the gunpowder be very inferior, sulphide of potassium (KS) is likewise formed.

70. *Chlorate of potassa* (KO, ClO_5) is obtained in the form of beautiful brilliant plates when chlorine is passed into a saturated solution of potassa.

This salt, containing so large a proportion of oxygen, burns with combustible substances still more vividly than saltpetre, and is, therefore, a very dangerous compound. It is employed as a constituent of the paste used in the manufacture of matches, in pyrotechny, and for the preparation of oxygen.

In combination with *silicic acid* (§ 61), potassa occurs in a large number of minerals, but particularly in *felspar* ($KO,SiO_3 + Al_2O_3,3SiO_3$), which contains, moreover, silicate of alumina. By the disintegration of this mineral the potassa becomes diffused in most soils, and there forms an essential constituent of the food of almost all plants, from the ashes of which it is subsequently prepared.

Artificial silicate of potassa is prepared by igniting three parts of sand with two of potashes. The fused mass is dissolved in water, and used, under the name of *water-glass*, for the purpose of coating combustible substances, and protecting them from the danger of fire.

When potassa is fused with a larger excess of silicic acid, a glass is obtained which will be more minutely described with the soda glasses.

15. SODIUM.

Symbol: Na = 23; Specific Gravity = ·972.

71. This metal is obtained from *carbonate of soda* (NaO,CO_2), precisely in the same manner as potassium from carbonate of potassa. It possesses all the properties of potassium, with the exception of not inflaming when thrown upon water; although it occasions rapid decomposition. If, however, a fragment of sodium be placed upon moist blotting-paper, it immediately ignites, and burns with a beautiful yellow flame. Moreover, the oxide of sodium (NaO), which is termed *soda*, and the sulphide of this metal, present in their preparation, properties, and applications, so great a similarity to the corresponding compounds of potassium that it is unnecessary here to describe them. We therefore pass at once to the consideration of those compounds of sodium possessing particular characters.

72. *Chloride of sodium* (NaCl) is better known under its familiar name of culinary salt, which we shall therefore adopt. Every one will acknowledge the importance of this body, which forms an indispensable constituent of the food of man and of many animals: without its presence the digestion of food would be impossible. It has received an important application in agriculture, and is the exclusive source whence we derive *chlorine* (§ 35), which is so important to the arts and manufactures; it is, moreover, the compound containing the chief constituent of soda (§ 73).

Culinary salt is by no means too abundantly distributed in Nature. Hence many disputes have arisen between nations with reference to this necessary compound, and many states have secured its cheap acquisition by commercial treaties. It is found partly in the solid form, as *rock salt*, and partly dissolved in the waters of *saline springs;* and, lastly, it is an invariable constituent of *sea-water*. To obtain it from these various sources, different modes are adopted. The rock-salt is obtained chiefly from the mines of *Salzburg*. To prepare it from the saline springs, the waters are evaporated until sufficiently concentrated to allow the salt to crystallize. If the waters contain from 15 to 20 per cent of salt, they are at once evaporated in the boiling pans; but if only a small per-

centage of salt is present, it is customary, with a view of saving fuel, first to evaporate or *graduate* them by exposure to the air. For this purpose the brine is allowed to percolate through high stacks of thorny faggots, called *graduating works*; by which means the air passing over the distributed liquid readily evaporates a large quantity of water. This process is frequently repeated until the brine is worth boiling. From the boiling pans the salt is obtained in the form in which we daily see it at our tables.

Sea-water contains on the average, about 2½ per cent of salt. In some parts of the coast of England the water of the sea is let into large shallow ponds, termed *salterns*, where, by the influence of sun and wind, it is slowly evaporated. The salt that is deposited is farther purified by re-solution and evaporation, but even then is inferior in quality to the salt obtained from salt brines.

The salt-works of Germany, particularly those of Luneburg, Reichenhall, Wimpfen, Rappenau, and Durrheim, are very rich, and yield from 23 to 25 per cent of salt.

73. In the neighbourhood of saline springs and of the sea, grow the so-called salt-plants (Salsola), which yield, when burned, an ash consisting principally of *carbonate of soda* (NaO,CO_2), or, as it is commonly termed, *soda*. The same salt, although less pure, is likewise obtained by the combustion of several marine plants. By far the greater quantity of soda, however, is at present prepared, in large manufactories, from the chloride of sodium. For this purpose, the chloride is first converted into sulphate of soda (NaO,SO_3) by heating it with sulphuric acid, hydrochloric acid (§ 36) being obtained as a secondary product. The sulphate of soda is then ignited with charcoal and carbonate of lime, by which means an insoluble oxisulphide of calcium and soluble carbonate of soda are formed. The carbonate is finally extracted by warm water, and brought into commerce in fine hydrous crystals, as *crystallized* soda, and partly in the anhydrous state, called soda-ash.

In its chemical properties this salt exhibits the greatest similarity to carbonate of potassa (§ 68); and for most of the purposes to which these salts are applied they may be mutually substituted. Soda, however, does not attract moisture from the atmosphere. Its principal use is in the manufacture of hard soap, glass, and in dyeing; its cost, moreover, is less than that of potashes. The crystallized soda, containing 63 per cent of water of crystallization, is of course much cheaper than that which is calcined.

74. *Sulphate of soda* (NaO,SO_3), which contains a large quantity of water of crystallization, is obtained, as above mentioned, in the fabrication of soda. This salt, which is frequently employed as an aperient, was discovered in the seventeenth century, and named, after Glauber, its discoverer, *the miraculous salt of Glauber* (sal mirabile Glauberi). It is employed in large quantities in the manufacture of glass. When 14 parts of *crystallized* Glauber's salt are finely pulverized, and mixed with 6 parts of sulphuric acid and 4 of water, the temperature sinks to 8° or 10° C. below zero (17·6° to 14° F.). If water contained in a narrow vessel be immersed in the mixture, it is very rapidly frozen. The cause of this phenomenon is due to the absorption of heat by the water of crystallization in passing from the solid to the liquid form, a change which is induced by the sulphuric acid (see Physics, § 146).

75. In the mineral kingdom, soda is found in combination with *silicic acid*

less frequently than potassa; but the minerals, natrolite, albite, and other silicious compounds containing soda, are by no means rare. We shall, however, first of all consider the artificial silicate of soda, which is called

Glass.

By this term is understood the transparent artificial compounds of silicic acid with metallic oxides. Glass never contains one oxide only, but several of these invariably occur together, and hence we may term it a mixture of silicates. The principal constituents employed in the preparation of glass are, *silicic acid* (sand), *soda*, *potassa*, *oxide of lead*, and *lime* (CaO), besides the colouring oxides, which are always added only in very small quantities. The kind of glass is determined by the prevailing oxide, and we distinguish in commerce the different varieties under the names of soda-glass, potassa-glass lead-glass, &c., which differ essentially in their properties.

Potassa-glass is the hardest and most difficult to fuse; moreover, it is the most colourless and transparent, and constitutes the chief mass of the magnificent *Bohemian crystal-glass*. The *soda-glass* was formerly manufactured principally in France, and is, therefore, called *French-glass*; it is softer and more easily fused, and has a bluish-green colour; it is principally used for windows. *Lead-glass* is the heaviest and fuses most readily, whereby it may be recognised without difficulty. The inferior kinds of it have a somewhat cloudy appearance, yet vessels which are made of them have a fine lustre, and they are particularly adapted for those glass-wares which are pressed between hot metallic plates. On the other hand, the purer kind of lead glass, termed *English flint-glass*, is distinguished by its transparency and remarkable power of refracting light, and is consequently employed in the manufacture of lenses. *Lime-glass* is a constituent of all kinds of glass, particularly of the green and yellow bottle-glass, which it renders more fusible. If a larger proportion of lime be used, a semi-transparent and white glass is produced, which is usually termed *milk-glass*.

76. In the preparation of glass, the constituents which are always mixed with broken glass are finely pulverized, dried by ignition, mixed according to the kind it is wished to produce, and then gradually projected into the melting pot. As many as six, eight, or ten of these crucibles are placed in an arched oven kept continually at a red-heat by a fire which is burning year after year. After the lapse of twelve hours, the mass melts, and at the expiration of twenty-four hours it is ready for working, a process which varies greatly according to the purposes for which the glass is required. The principal tool of the glass-blower is the so-called *blow-pipe*, consisting of an iron tube from three to four feet long, which he dips into the melted mass, and then blows out the adhering glass precisely in the same manner as we make bubbles of soap. By suitable rolling, stretching, bending, and moulding, the workman gives to his ball all possible shapes, and cuts with a pair of scissors the soft glass wherever he deems it necessary, exactly as we cut a piece of paper. If it is intended to make sheet or window-glass a long hollow cylinder is blown, which is first cut open at the lower extremity and then in a longitudinal direction. The sheets are then stretched in a particular kind of oven, and polished. Large plates for mirrors are cast, and then submitted to the tedious and troublesome

processes of grinding and polishing, which make this kind of glass exceedingly dear.

77. Coloured glass is obtained by the addition of certain metallic oxides to the melted mass, and these we will mention with the corresponding colours. Black glass is produced by a mixture of protoxide of iron, binoxide of manganese, protoxide of copper, and oxide of cobalt; blue, by oxide of cobalt; violet, by binoxide of manganese; green, by protoxide of copper, or sesquioxide of chromium; bottle-green, by protoxide of iron; purple-red, by oxide of gold with binoxide of tin; ruby, by suboxide of copper; flesh-colour, by sesquioxide of iron; and yellow, by teroxide of antimony and protoxide of silver.

Transparent, highly lustrous, coloured lead glass, termed glass-flux or strass, is employed in the fabrication of the artificial precious stones, and the brilliant glass pearls. An addition of binoxide of tin renders the white or coloured glass opaque, in which case it is called enamel, and is used for necklaces and all kinds of ornaments.

The art of painting on glass consists of two different processes—either differently-coloured pieces of glass are united by means of lead, or coloured glass-flux is burnt into the surface of the glass; the colour is then on certain parts ground or etched out by hydrofluoric acid (§ 39), and other glass-fluxes burnt in, whereby the required designs are produced. Those colours which are capable of standing the least heat are placed on last. This noble art has been particularly investigated by the chemist, and at the present time the most magnificent colours are obtained.

AMMONIUM.

78. As will be shown in the subsequent part of the work, we find in all liquids obtained in the dry distillation of nitrogenous bodies, a volatile compound of nitrogen and hydrogen which possesses all the properties of a powerfully basic metallic oxide, and has received the name of *ammonia* (NH_4O). This combination is obtained in a state of purity when chloride of ammonium (NH_4Cl) is heated with caustic lime, and the evolved gas passed into water.

Solution of ammonia (NH_4O), usually termed *spirit of sal-ammoniac* or hartshorn, is a pellucid liquid of penetrating odour and taste, producing a powerfully irritating effect upon the eyes. The abundant formation of ammonia from decaying animal refuse is amply testified by the powerful odour continually emitted by these bodies during decomposition, particularly in moist weather. The formation appears to depend chiefly on the presence of a large quantity of moisture, for when, by suitable arrangements, the liquid contents of cesspools and sewers are allowed to drain off, the generation of this compound is greatly retarded.

Chloride of ammonium (NH_4Cl) is obtained when the alkaline liquid produced in the distillation of animal matters is saturated with hydrochloric acid, and the solution evaporated and sublimed. It occurs as a white salt, commonly termed *sal-ammoniac*, in consequence of having been originally imported from the province of Ammonium in Egypt, where it was prepared by distillation of camel's dung.

Carbonate of ammonia (NH_4O,CO_2) crystallizes from the above-mentioned alkaline liquid, and is purified by frequent solution and recrystallization.

All the compounds of ammonia possess a peculiarly sharp taste, and evolve when mixed with lime the pungent odour of the liquid compound. They are highly valuable remedial agents, acting particularly upon the cutaneous system, and when taken internally, produce the effect of powerful sudorifics. Their *volatility*, and the facility with which they are expelled from other substances render them of great importance in chemistry, and peculiarly fit them for the purposes of many chemical analyses. The ammonia compounds display a remarkable analogy to the corresponding combinations of potassa and soda; and hence we observe that a similar series of phenomena are produced in certain cases when ammonia is substituted for potassa or soda, or when the carbonate of ammonia or sulphide of ammonium is employed in the place of the carbonates of potassa and soda or the sulphide of potassium.

Moreover, the compounds of ammonia are highly important in their relation to the vegetable kingdom. It may be assumed that all the *nitrogen* of plants is derived from the ammonia which they absorb from the soil and from the surrounding atmosphere.

The similarity of ammonia to the metallic oxides has led to the conjecture that all its combinations contain a *compound* metallic body, which has received the name *ammonium* (NH_4); but no one has yet succeeded in its preparation, although by peculiar processes it may be obtained in the form of an amalgam.

16. CALCIUM.

Symbol: $Ca = 20$.

79. This metal forms a considerable part of the solid crust of the earth, entire mountains consisting of the carbonate of its oxide (chalk); it is also a never-failing constituent of plants and animals. In the free state it offers little interest, and owes its importance chiefly to its combinations. We shall first consider—

Oxide of calcium, or *lime* (CaO), which is obtained by the ignition of carbonate of lime (CaO,CO_2), when the carbonic acid is evolved. On the large scale the process is carried on in furnaces called *lime-kilns*.

The properties of lime are familiar to every one. It possesses a grayish-white appearance, and when moistened with water it combines, with considerable development of heat (Phys. § 147), to produce hydrate of lime (CaO,HO), which is ordinarily termed *slaked lime*. The caustic lime when thus treated swells up and cracks, and finally crumbles to an impalpable powder. On addition of a farther quantity of water a milky liquid is produced, which is commonly termed *milk of lime*, and from which is deposited a portion of the lime in form of a pasty mass, whilst the clear supernatant liquid is found to be a solution of lime in water, and is called *lime-water*.

Lime is powerfully caustic, hence called *caustic lime*, and attracts carbonic acid with great avidity from the air, whereby it is again converted into carbonate and completely deprived of its caustic properties. If a paste of lime be exposed to the atmosphere, it becomes in a short time converted into hard carbonate of lime, a property on which depends its important application to *mortars* and cements.

Caustic lime is employed in white-washing, and for the purpose of depriving

skins of hair in the process of tanning (technically called unhairing), as well as in many chemical operations.

80. *Carbonate of lime* (CaO,CO_2), like silicic acid and carbon, occurs in Nature under a variety of forms. *Calcspar* is colourless, transparent, and crystallized; *marble* is white, granular, and hard; whilst *chalk* is soft, and leaves a mark when drawn across a coloured surface. Other limestones, moreover, are coloured by the admixture of metallic oxides; thus we meet with gray, yellow, black, brown, red, and even with variegated limestones, such as many of the beautiful kinds of marbles. But, notwithstanding their diversity of form and appearance, they, one and all, are characterised by giving rise to a powerful evolution of carbonic acid, when treated with hydrochloric acid, and by yielding caustic lime by ignition.

Carbonate of lime, in all its forms, is an important material, not only for the sculptor, but also as a building-stone and cement for masonry; its comparatively trifling hardness, however, renders it ill adapted for the purpose of constructing roads.

Carbonate of lime is the main component of the shells of the crustacea, of corals, and of the shell of the egg; it enters likewise into the composition of bones, and hence we must regard it as one of the necessary constituents of the food of animals. Although this salt by itself is insoluble, it is nevertheless an almost invariable constituent of the waters we meet with in Nature, containing, as they always do, a portion of carbonic acid, which has the power of dissolving carbonate of lime. But when gently warmed, the volatile gas is expelled and the carbonate of lime deposited in the form of a white incrustation upon the bottom of the vessel. Every household daily affords us opportunities of witnessing deposits of this nature, which are particularly observed on the bottoms of tea-kettles, and if the water contains a large quantity of calcareous matter, even our water-bottles and drinking-glasses become covered with a thin film of carbonate of lime. These depositions may readily be removed by pouring into the vessels a little dilute hydrochloric acid, or some strong vinegar, which in a short time dissolves the carbonate of lime.

81. *Sulphate of lime* ($CaO,SO_3 + 2HO$) is found in considerable masses, and is commonly known under the name of *gypsum*. It occurs either crystallized or granulated, and of dazzling whiteness resembling sugar; in the latter form it is termed *alabaster*, which is so soft as almost to admit of being cut with a knife, and is admirably adapted for various kinds of works of art. Gypsum, as shown by the formula, contains water of crystallization, which is expelled at a gentle heat. But when ignited, ground, and mixed into a paste with water, it acquires the property of entering into chemical combination with it, and forming the original hydrate which in a short time becomes perfectly solid. Thus it offers to the artist a highly-valuable material for preparing the well-known plaster figures, and by its use the noblest statues of ancient and modern art have now been placed within the reach of all.

Gypsum, moreover, has received a valuable application as manure, to which we shall again return in our consideration of the nutrition of plants. In water it is slightly soluble, and imparts to it a disagreeable and somewhat bitterish earthy taste.

Phosphate of lime constitutes the principal mass of the bones of animals, and is extensively employed in the preparation of phosphorus; in the form of

ground bones it is likewise used as a manure. It appears to belong to those mineral constituents which are essential to the nutrition of animals, being found in the seeds of all the cereals, from which, especially those used in bread, is derived the phosphorus contained in the animal organism.

Silicate of lime we have already become acquainted with as a constituent of glass. A number of minerals and mineral remains contain silicic acid and lime: we shall, however, allude here only to the compound known under the name of *hydraulic mortar*, or cement, the principal constituents of which are silicic acid, lime, and alumina. It occurs in nature as the so-called *strass*, or it is prepared artificially. When finely pulverized and mixed into a paste it quickly hardens, even under water, and hence it is employed with great advantage in the construction of masonry under water, and for the purpose of protecting many buildings against the action of water.

CHLORIDE OF LIME.

82. When chlorine is passed over hydrate of lime (§ 79), thinly spread upon trays, there is formed a mixture of lime (CaO), chloride of calcium (CaCl), and hypochlorite of lime (CaO,ClO). This compound is met with in commerce in the form of a moist white powder, smelling slightly of chlorine, and is generally known under the name of chloride of lime, or *bleaching powder*.

Chloride of lime evolves chlorine very abundantly when treated with the weakest acids, and even the carbonic acid of the atmosphere suffices to decompose it; hence it offers at the same time the most convenient and frequently-used substance for preparing this very important element. Whilst chloride of lime is employed in enormous quantities in bleaching establishments, we continually avail ourselves of its disinfectant properties in our dwellings, and particularly in anatomical rooms, hospitals, &c. For the latter purpose we place about a table-spoonful of the powder in a saucer, and add to it an equal quantity of hydrochloric acid diluted with a little water, taking great care to avoid the inhalation of the pure chlorine. The doors and windows of the rooms must be previously closed, and opened again after some hours. If, however, the chlorine is needed in an inhabited room, it is advisable to add from time to time only a few drops of hydrochloric acid, always bearing in mind that too much chlorine is very pernicious. If it be desired to bleach written papers, soiled engravings, &c., a filtered solution of the chloride of lime is decomposed with a few drops of hydrochloric acid, and the object immersed in this liquid until the desired effect is produced. The paper is then frequently rinsed and allowed to remain for some hours in a large vessel of pure water, and afterwards dried between folds of blotting-paper. Ink-spots are removed by this process with equal facility.

17. BARIUM.

Symbol: $Ba = 68 \cdot 5$.

83. This metal occurs much less frequently than the one we have just described. Its most important compound is the so-called *heavy-spar* or *sulphate of baryta* (BaO,SO_3) which is a white, compact crystalline mineral, and is

distinguished from all the other earthy compounds by its great specific gravity, which is = 4·44. When ground to a fine powder, it is employed as a white paint; all the inferior kinds of white lead are largely adulterated with heavy-spar. The sulphate of baryta is perfectly insoluble in water.

Nitrate of baryta (BaO,NO_5) is used in pyrotechny for preparing a green fire, for which the following mixture is employed: 20 parts by weight of sulphur, 33 parts of chlorate of potassa, and 80 parts of nitrate of baryta.

18. STRONTIUM.

Symbol: $Sr = 43 \cdot 8$.

84. This somewhat rare metal is distinguished by imparting to flame an extremely beautiful crimson colour, and on this property depends its only application. If we dissolve the *chloride of strontium* ($SrCl$) in spirits of wine, it imparts to the flame a beautiful red tint.

We may obtain a splendid red fire by burning the following *dry* mixture: 10 parts of nitrate of strontia; 1½ part of chlorate of potassa; 3½ parts of sulphur; 1 part of sulphide of antimony; and ½ part of charcoal.

19. MAGNESIUM.

Symbol: $Mg = 12 \cdot 2$.

85. Magnesium is frequently met with in combination, and occasionally forms one of the principal constituents of certain mountains. Its soluble compounds are distinguished by a bitter taste and aperient effect, and are almost exclusively employed in medicine. Its oxide is termed *magnesia*.

Chloride of magnesium ($MgCl$) is a constituent of sea-water, to which it imparts its disagreeable taste, and renders it unfit for the ordinary purposes of life. This salt is likewise contained in many saline springs.

Sulphate of magnesia (MgO,SO_3) occurs in sea-water, and in very large quantities in many saline springs, as in those of Epsom, Seidschütz, Kissingen, and many others, from which it is obtained.

Carbonate of magnesia (MgO,CO_2) forms with carbonate of lime a compound called *dolomite*, a rock which occurs in masses of considerable size. In the pure state it is prepared by decomposing a hot solution of sulphate of magnesia with carbonate of soda. When dried it forms an extremely light, flocculent, white powder, which is insoluble in water, and, therefore, tasteless. By ignition it loses its carbonic acid, and is then pure oxide of magnesium (MgO), which is employed in medicine, under the name of *calcined magnesia*, particularly for acidity of the stomach.

20. ALUMINUM.

Symbol: $Al = 13 \cdot 7$; Specific Gravity $= 2 \cdot 6$.

86. This metal forms a considerable part of the crust of our earth, since its oxygen-compound (Al_2O_3), which is termed *alumina*, constitutes, next to silicic acid and lime, the mass of the greater number of minerals. Like several other bodies, which we have already become acquainted with, alumina presents itself in a great variety of forms. (*Mineralogy*, § 43.)

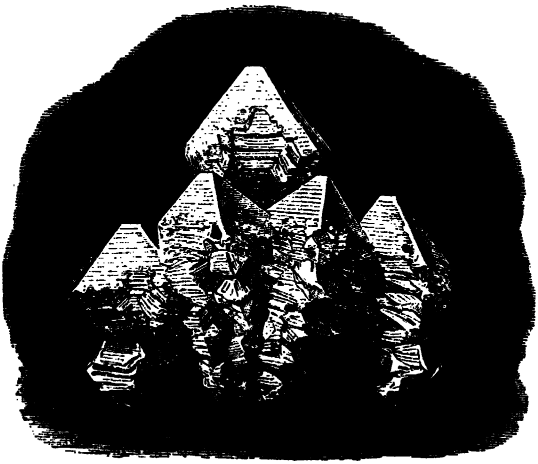
Crystallized alumina is found under the same circumstances as crystallized

carbon, and hence the *sapphire*, consisting of pure alumina, and distinguished by its hardness, lustre, and infusibility, is numbered amongst the precious stones. The minerals *corundum* and *emery*, which are alumina of a less degree of purity, likewise possess considerable hardness, and owing to this property they have received an important application in grinding and polishing other substances.

Pure alumina may be chemically prepared by precipitating a solution of alum by ammonia. The gelatinous precipitate, when washed and dried, forms a white, insoluble, and infusible mass, which strongly adheres to the tongue.

Alumina is distinguished by its great affinity for vegetable fibre and colouring matters. If we place some threads, or a piece of cotton or linen texture, in a solution, and precipitate the alumina, the oxide is found to enter into intimate combination with the fibre; and if the cloth thus prepared be now immersed in a solution of a colouring matter, the alumina fixes a portion of the colour upon the fibre, which then appears to be permanently dyed. This property renders alumina an important material in the process of dyeing. The insoluble precipitates which alumina forms with vegetable colouring matters are known under the name of *lakes*.

87. *Alum* is a compound of sulphate of alumina with sulphate of potassa ($Al_2O_3,3SO_3 + KO,SO_3 + 24HO$), which is found in Nature, but is chiefly prepared artificially. It possesses a sweetish, astringent taste, crystallizes in large colourless double pyramids (fig. 40), and is soluble in water; it is employed in enormous quantities in dyeing, and in the preparation of other alumina-compounds, particularly of the *acetate of alumina*.



40.

The compounds or mixtures of alumina and silicic acid perform an important part in the economy of Nature and of man. A number of hard minerals consist of silicate of alumina, and give rise, by their disintegration, to an earthy mass, which is commonly termed *clay*. According as they are mixed with other metallic oxides, the clays possess various colours, and are distinguished by particular names; thus we have the white Cologne pipe-clay, fuller's-earth, porcelain-earth, gray clay, yellow clay or loam, and brown and red clays. All these kinds of clay have the general property of adhering more or less strongly to the tongue, and possess a peculiar odour, termed the clay-odour, which is probably due to the continual absorption of ammonia from the atmosphere.

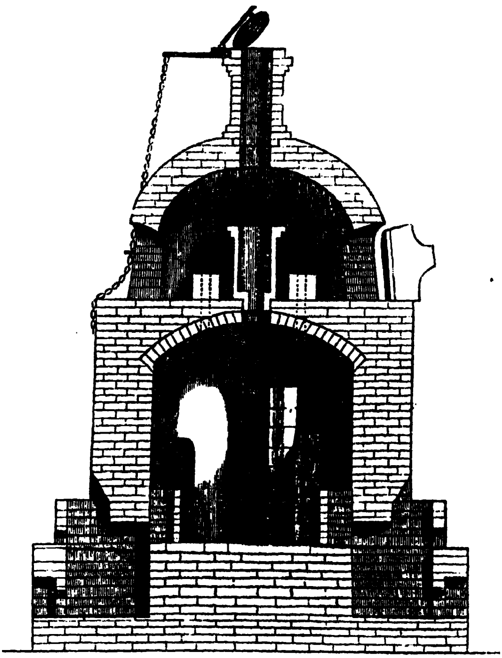
Clay produces with water a soft, plastic mass, which retains moisture with extraordinary power, a property which renders it of the greatest importance to agriculture, and secures to plants the moisture needed for their growth.

The plasticity of moist clay has led to its employment from the earliest times in the manufacture of pottery. When the soft vessels of clay are ignited, or, as it is commonly termed, *fired*, they acquire considerable hardness. The names by which they are distinguished depend upon the fineness and purity of the clay.

Porcelain.

88. Porcelain which has long been known to the Chinese, was discovered in Germany in the year 1701, by Böttcher, a chemist of Meissen, who, by the command of Prince Joachim of Saxony, engaged in the attempt to make gold. This chemist mixed and fused together a variety of substances, and finally his labours were crowned with the discovery of a beautiful semi-transparent substance, which we term porcelain, and which, indeed, has proved a true mine of gold to the kingdom of Saxony.

A variety of clay, called porcelain-earth, which is free from iron, is found in many localities, and is the principal constituent required in the fabrication of porcelain. This clay is finely ground, and intimately mixed with a portion of pure silicic acid or gypsum. From the mass thus prepared the vessels are formed, partly by hand on the potter's wheels, and partly by the aid of moulds, upon which these plates of clay are pressed by means of a soft sponge. After the vessels have been slowly dried in the air, they are submitted to the first process of burning, and, in order to prevent them being soiled, they are put into clay capsules, and placed in the coolest part of the potter's kiln (fig. 41). The vessels thus become hard and perfectly white, but their appearance is dull and earthy, and as the mass imbibes water very powerfully, they adhere strongly to the tongue.



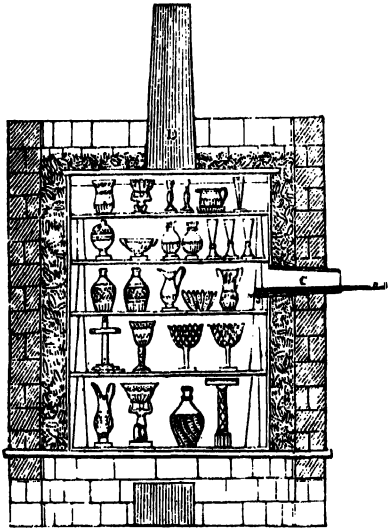
41.

The porcelain now requires to be *glazed*, for which purpose it is immersed in a liquid consisting of finely-levigated porcelain-earth, which is rendered more

easily fusible by addition of gypsum. When thus covered with glaze, the vessel is a second time fired, at a heat approaching to whiteness.

The superior kinds of porcelain are perfectly white, very hard, and produce sparks when struck with steel. They exhibit a lustrous and conchoidal fracture, and are semi-transparent. Vessels of porcelain which are very thin produce a tone almost as clear and pure as that of metal.

In painting porcelain, a mixture is used consisting of oil of turpentine and coloured glass (§ 77), which is laid on the vessels already glazed, and then burnt in, at a very gentle heat, in the muffle-oven (fig. 42).



42.

The superior Fayence porcelain exhibits a white earthy fracture, and is glazed with the most readily-fusible lead-glass. But vessels of inferior quality present a gray, yellow, or red fracture, and in that case they are glazed with a white glaze of lead-glass and binoxide of tin.

Earthen-ware, or earthen vessels, are made of coarser clay, and are either unglazed, as flower-pots, or they receive a coating of lead-glass, and it not unfrequently happens that, in the attempt to save fuel, the oxide of lead required for the glaze is not perfectly vitrified, and thus the food preserved in such vessels occasionally acquires poisonous properties; it is, therefore, necessary to select well-burned, clear-sounding, and highly-glazed vessels.

Another kind of pottery, which is called *stone-ware*, and is especially used in making bottles, preserve-pots, &c., is glazed by means of chloride of sodium, which is projected into the red-hot oven containing the various vessels. The salt volatilizes, and covers the interior as well as the exterior of the wares with a coating of readily-fusible soda-glass.

An inferior kind of clay is manufactured into tiles and bricks, which generally present a red colour, due to the presence of sesquioxide of iron.

89. The rare mineral known under the name of *lapis lazuli* forms, when finely ground, the magnificent blue colour called *ultramarine*. Chemical investigations have shown that this mineral consists of sulphide of sodium (§ 71) and silicate of alumina; by igniting these substances together in proper proportions this magnificent colour is now artificially produced. Hence the price of ultramarine, which formerly was equal to that of gold, is now so low as to admit of this substance being employed in painting, in the manufacture of paper-hangings, and for many other purposes.

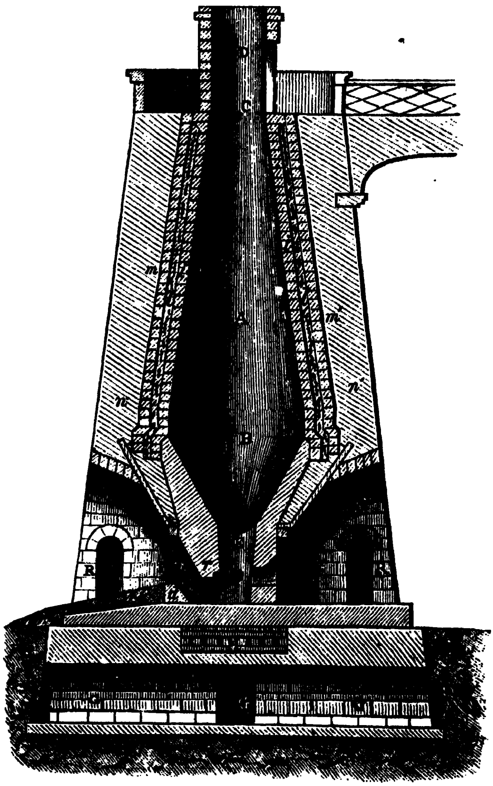
(B.) HEAVY METALS.

21. IRON (FERRUM).

Symbol: Fe = 28; Specific Gravity = 7·8.

90. We commence our description of the heavy metals by giving an account of iron, which is the most important and valuable of all the metals. Of this we fabricate the plough, with which we till our fields, and the sword, wherewith to defend them. History affords us many proofs that by the possession of a surplus of gold industry becomes in a measure suspended; whilst on the other hand, the possession of iron, the true source of wealth, has led to the boundless developement of arts and manufactures.

In our section on Mineralogy we shall describe a number of ores from which iron is obtained, and which are particularly abundant in this country, and also in Germany and Sweden. The essential constituents of these ores are *iron* and *oxygen*, from which the latter element has to be separated. For this purpose the ores are broken in small fragments, mixed with limestone and coal, and introduced into the blast-furnace (fig. 43). The cone of the furnace A. is surrounded by fire-bricks, *i i*, which is again enveloped in a casing, *l l*, formed of broken scoriæ, and which separates the internal lining of the furnace from the external coating of fire-bricks, *m m'*, supported by a mass of masonry, *n n'*, formed either of stone or bricks. The opening C, at the top of the furnace is called the *throat*, or *tunnel-hole*, and is surmounted by a chimney, D. The lower cone B, is known by the name of the *boshes*, and is constructed generally of fire-stone. At the commencement of the process, the bottom of the furnace is filled with wood and coal which is ignited, and the fire is afterwards maintained in a state of intense ignition by a powerful and continuous blast of air. As soon as the ore has become thoroughly ignited, its oxygen unites with the carbon to produce carbonic acid, which escapes, whilst the metal itself fuses,



43.

and flows to the bottom of the furnace, whence it is from time to time allowed to run out. As the lower stratum fuses, the one above falls down, and by the continual addition of fresh quantities of ore and coal to the upper part of the furnace, the process is continued year after year without interruption, until at last the heat seriously injures the walls, which then require either to be rebuilt or repaired.

Iron, however, is not the only product of the blast-furnace. By far the greater number of ores contain, moreover, silicic acid, alumina and lime, which by the heat required for the separation of the iron, and by the limestone added for the purpose of removing the silicic acid and alumina, become fused to a dark-coloured glass, termed *slag*, which flows with the melted metal to the bottom of the furnace. The slag, being much lighter than the iron, floats upon the surface, and is from time to time removed by rakes, and then solidifies to a vitreous mass. The slag which covers the surface of the melted iron protects it from the atmosphere, which would otherwise oxidize a considerable quantity of metal: hence the necessity of slag in the blast-furnace process; when the ores do not contain those constituents necessary for its formation, it is usual to introduce such minerals, and especially lime, as produce a readily-fusible slag.

Varieties of Iron.

91. Carbon has the property of entering into chemical combination, and of being *dissolved* by iron; and according to the proportion in which it is present we obtain the three principal varieties, namely (1.) Cast-iron, containing a considerable quantity of carbon. (2.) Wrought-iron, free from carbon. (3.) Steel, or iron which is combined with a very trifling quantity of carbon.

(1.) The metal which is immediately drawn from the blast-furnace is termed *pig* or *cast-iron*. 100 pounds contain about 5 pounds of carbon, which is either in perfect chemical combination or only *partly* dissolved. In the former case, the iron is white, lustrous, and forms the variety distinguished as *specular-iron*, which, on account of its tenacity and difficulty of fusion, is unsuited for casting, and is employed in the preparation of the other kinds of iron. In the latter case, the iron possesses a grayish or blackish-gray colour, as observed in the ordinary cast-iron or gray pig-iron. This variety fuses at 1000° C. (1832° F.) to a mobile liquid mass, which readily flows into all parts of the moulds of sand. On cooling, it contracts only to the extent of about 1½ per cent, and therefore it is admirably adapted for all kinds of castings, particularly for furnaces, hearth-plates, and for numberless objects of art. This kind of iron, which exhibits a granulated fracture, is extremely hard and brittle, and does not admit of being worked in any other way.

(2.) *Bar* or *wrought iron* is found to be almost pure iron: it is prepared from the foregoing by powerful ignition, in contact with the atmosphere, whereby the carbon it contains is burned, until scarcely a trace remains. The most remarkable property of this kind of iron is extreme tenacity, which allows it to be wrought with facility, and drawn into fine wires, or rolled into plates, but, owing to its trifling hardness, it is little suited for the manufacture of cutting instruments. Its fracture is gray and jagged, and, when worked, its surface acquires considerable polish, and has then a white colour. Bar-iron fuses only at the strongest white heat, at about 1600° C. (2912 F.), and

hence the difficulty of joining two pieces together by fusion; but at a red-heat the iron becomes sufficiently soft to admit of being intimately united by hammering, or, as it is commonly termed, *welded* together

(3.) Steel contains from 1 to 2 per cent of carbon. It is either prepared from cast-iron, by the removal of only part of its carbon, or from bar-iron, to which some carbon is again added. The steel prepared by the first process is called *raw* or cast-steel. In the second process, the bars of iron, surrounded by pulverized charcoal, are for some time ignited in earthen vessels, whereby the carbon slowly combines with the iron, and converts it into the so-called *cement-steel.* Larger masses of iron, when treated in a similar manner, have their surfaces only converted into steel, or, as it is commonly termed, *cemented.*

Steel offers one of the most remarkable examples of the *dissimilar* properties one and the same body may acquire by the different arrangement of its particles. By itself it possesses nearly all the characters of bar-iron: it is soft and malleable, but it is more readily fusible, since it fuses at a temperature of from 1200° C. to 1400° C. (2192° F. to 2552° F.); its colour likewise varies from gray to grayish-white, but it is susceptible of an extremely fine polish, and acquires thereby a high lustre. If, however, the red-hot steel be suddenly cooled by plunging it into cold water, it becomes entirely changed in its nature, being then extremely brittle and unmalleable, and harder than any other substance, with the exception of the diamond and crystallized alumina. It scratches glass and flint, and is chiefly employed in the fabrication of instruments, in which great hardness is required, such as files, needles, &c.

When *hardened* steel is heated and allowed to cool slowly it loses its properties, and acquires again the softness and tenacity of raw steel. The stronger the heat employed, the more completely is this remarkable change produced; and by employing suitable temperatures, intermediate qualities of steel may be obtained, which, in addition to greater hardness, acquire at the same time considerable flexibility; a property which is absolutely indispensable for most of the purposes to which it is employed, and particularly for the fabrication of cutting instruments. By heating or *annealing*, the polished steel changes its colour, becoming first of a pale yellow, then dark yellow, orange, red, dark red, violet, blue, and finally blackish-blue, the darker colours being produced by the higher temperatures. These changes of colour observed in steel afford, therefore, an excellent means of judging of the temperatures to which it must be exposed when the steel is required for certain purposes. This series of colours may be distinctly seen by holding a knitting-needle in the edge of a candle-flame, when at the hottest part the needle will appear of a black colour, passing through all the other tints towards the cooler extremity.

In most manufactories of steel, the objects are first formed of the soft raw steel, then hardened, and subsequently, to a certain extent, annealed, according to the purpose for which they are required, as we will illustrate by the following examples: *pale yellow* for the finest knives; *golden yellow* for razors and penknives; from *brown* to *purple-red* for scissors, axes, chisels, and ordinary knives; *bright blue* for swords, watch-springs, and gimlets: and, finally, *dark blue* for the blades of saws.

Compounds of Iron.

92. In general, the compounds of iron which are soluble in water possess a peculiar *chalybeate* taste, which any person may become acquainted with by tasting ink. They have, moreover, the property of forming a dark-blue, or violet compound (ink), with an infusion of gall-nuts or of oak bark, and with *all substances containing tannic acid. In most of its compounds* iron possesses medicinal properties, and acts especially upon the blood.

(1.) *Protoxide of iron* (FeO) is only known in combination. Its hydrate (FeO,HO), which is prepared by precipitating a solution of sulphate of iron, or green vitriol, by potassa, is white, but becomes in an instant green, then yellow, and finally brown, passing slowly into the higher oxide.

(2.) *Sesquioxide of iron* (Fe_2O_3) occurs frequently as a mineral, called red iron-stone, and is obtained as a residuary product in the manufacture of fuming sulphuric acid (§ 41). When pulverized, it appears of a dark brick-red colour, and is employed in polishing plate, &c., under the name of *English rouge.* The colour of red-ochre, red-chalk, and red-sandstone, is due to the presence of this compound. The hydrate of the sesquioxide ($Fe_2O_3,3HO$) is frequently met with in Nature under the name of brown iron-stone. It varies in colour from yellow to brown, and imparts to loam, tripoli, &c., their peculiar tints. In the pure state it is prepared by precipitating a solution of sesquichloride of iron by ammonia, and is employed in medicine as an antidote for arsenic (§ 46). It constitutes, moreover, the rust which is seen on iron exposed to the influence of moist air.

(3.) *Bisulphide of iron* (FeS_2), occurring in Nature, and commonly known as *iron pyrites*, is crystalline, and exhibits a metallic lustre, and brass-yellow colour. The ordinary black sulphide (FeS), which is frequently employed in the preparation of hydrosulphuric acid (§ 43), is prepared by gently igniting equal parts by weight of sulphur and finely-divided iron.

(4.) *Chloride of iron* ($FeCl$) is formed when iron is dissolved in hydrochloric acid. It is deposited from a concentrated solution in the form of pale, greenish-blue, hydrated crystals. The sesquichloride of iron (Fe_2Cl_3) is obtained in reddish-brown hydrated crystals from a concentrated solution of iron in aqua regia (§ 36), and is extensively employed in medicine.

(5.) *Cyanide of iron* forms, with cyanide of potassium, a remarkable compound ($FeCy,2KCy$), known under the name of *prussiate of potash* or ferrocyanide of potassium. It is produced when nitrogenous carbon (§ 50) is strongly ignited with potassa, and the mass so obtained subsequently boiled with metallic iron. The concentrated and filtered solution deposits, on cooling, beautiful yellow crystals of ferrocyanide of potassium of the above-mentioned composition, containing, moreover, three equivalents of water of crystallization. A solution of this salt produces, with the soluble compounds of protoxide of iron, a pale-blue precipitate, which in a short time acquires, by exposure to the atmosphere, a beautiful dark-blue colour; but with a solution of the sesquioxide of iron, it immediately forms a fine dark-blue precipitate of *Prussian blue*, which is a compound of cyanogen and iron. The inferior and paler varieties of this much-employed pigment are prepared by adding to the blue deposit, whilst still moist, a portion of finely-levigated white clay. Although this compound contains cyanogen, it nevertheless appears to produce no

poisonous effect upon the animal economy. It may be remarked, that the ferrocyanide of potassium is employed in the preparation of hydrocyanic acid and most of the other cyanogen compounds. (Compare § 59.)

93. (6.) *Sulphate of protoxide of iron* ($FeO,SO_3 + HO$), or green vitriol, forms beautiful green hydrated crystals. It is obtained in large quantities by the oxidation of iron pyrites, and is one of the cheapest salts. The most important purposes to which it is applied is the preparation of Prussian blue, ink, violet and black dyes, fuming sulphuric acid, and most of the preparations of iron.

(7.) *Carbonate of protoxide of iron* (FeO,CO_2) is obtained by precipitating a solution of the preceding salt with carbonate of soda. Its colour is first white, but rapidly changes to green and brown from the absorption of oxygen and partial conversion into the sesquioxide. Although insoluble in water, it is nevertheless found in numerous springs which contain much *carbonic acid*, being held in solution by this gas: the waters which hold the iron in solution by this means are commonly termed *chalybeate* waters.

22. MANGANESE.

Symbol: $Mn = 27 \cdot 6$; Specific Gravity $= 8$.

94. Manganese is, next to iron, the most diffused of all the heavy metals, although it is only rarely met with in considerable quantities. There is scarcely an iron ore that does not contain manganese, and hence the iron of commerce almost invariably contains a portion of this metal, occasionally amounting to 4 or 6 per cent.

The metal itself is extremely difficult to prepare in a state of purity, and so hard to fuse that it at present has received no useful application. Its most important compound is the *binoxide of manganese* (MnO_2), which yields a portion of its oxygen with great facility, and is, therefore, extensively employed as a means of oxidation, and for the preparation of oxygen (§ 22). It is used, moreover, in the arts for decolorizing glass, and in enormous quantities for preparing chlorine (§ 35).

Protoxide of manganese (MnO) is employed for imparting a violet colour to glass.

When the binoxide is ignited for a considerable time with potassa, and the mass subsequently treated with water, a beautiful green solution is obtained, consisting of *manganate of potassa* (KO,MnO_3), the colour of which, on farther dilution and exposure to the atmosphere, changes to a beautiful purple-red, the *permanganate of potassa* (KO,Mn_2O_7) being then contained in the liquid. This compound, however, likewise slowly decomposes, and the solution finally becomes colourless. On account of these peculiar changes of colour, the green compound has received the name of *mineral chamelion.*

23. COBALT. 24. NICKEL.

Symbol: $Co = 29 \cdot 5$; Specific Gravity $= 8 \cdot 7$. Symbol: $Ni = 29 \cdot 6$; Specific Gravity $= 8 \cdot 8$.

95. These two metals occur mostly together, and in a similar state of combination, as ores, which contain besides a portion of sulphur and arsenic. To remove these latter substances the ores are ignited with potassa and nitre, whereby we obtain the soluble arseniate and sulphate of potassa, whilst the

oxides of the metals remain behind, and are then employed for the preparation of their respective compounds. Both metals are hard, brittle, difficultly fusible, and attracted by the *magnet.*

Oxide of cobalt produces, with silicic acid, a deep-blue vitreous compound (§ 77), which acquires a light-blue colour when finely pulverized, and then forms the pigment known as *smalts.* The salts of cobalt possess a rose-red or blue colour; and it may be remarked, that the chloride is used as a sympathetic ink. If paper be written upon with a solution of this salt, the writing remains invisible, but when gently warmed it appears of a beautiful blue colour. If to the cobalt solution a few drops of chloride of iron be added, the writing then acquires a splendid green colour.

The most important application of nickel is in the preparation of the alloy it produces with zinc and copper, which is called *German-silver* or argentine, and possesses properties closely allied to those of silver. The salts of nickel have a beautiful green colour.

25. COPPER.

Symbol: Cu = 31·7; Specific Gravity = 8·9.

96. Copper possesses a beautiful red colour, and is very tough and malleable; it possesses moderate hardness, and requires a very high temperature for fusion. This metal is frequently met with in the native state, and hence it became known to the ancients long before iron, which is difficult to reduce to the metallic form. It frequently occurs, moreover, in combination with oxygen or sulphur.

Sheet copper, as well known, is worked into a great variety of domestic utensils, particularly tea-kettles, saucepans, stills, &c.; and it possesses the great advantage over iron that it is little affected by exposure to the atmosphere. With other metals it combines to produce a series of alloys, which are used for many purposes. The most important of these alloys are the following: 1. *Brass,* which consists of 71 parts of copper and 29 parts of zinc, has a bright yellow colour, and is commonly employed in castings. 2. *Red brass,* termed also tomback or similor, consists of 85 parts of copper and 15 of zinc. When beaten into thin leaves it constitutes the spurious leaf-gold, the powder of which is used in imitative gilding and bronzing. 3. *Bronze,* which was especially used in antiquity for the fabrication of utensils and works of art of every kind, consists of from 85 to 97 parts of copper, and from 15 to 3 of tin. 4. *Gun-metal* contains 90 copper with 10 tin. 5. *Bell-metal* is 75 to 80 parts copper, and 25 to 20 tin. 6. *German-silver,* or argentine, consists of 2 copper, 1 nickel, and 1 zinc. 7. *Coinage silver* and *plate,* and likewise *coinage gold,* invariably contain a small quantity of copper, for the purpose of imparting additional hardness.

Compounds of Copper.

97. The compounds of copper, in so far as they are soluble, are distinguished by a nauseating metallic taste, which is evident when an object of brass or copper is placed in contact with the tongue. Taken internally they act as poisons, and for this reason the vessels of copper are now, as far as practicable, abolished in domestic economy. But, nevertheless, cases of poisoning by

copper frequently occur; and, as a remedial means, it is usual to administer, in the first place, an emetic, and afterwards copious draughts of sugared water. The prevailing colours of the compounds of copper are blue and green.

(1.) *Protoxide of copper* (CuO) is formed as a black mass when metallic copper is ignited in the atmosphere. The hydrate of this oxide (CuO,HO) is obtained in the form of a beautiful blue precipitate when a solution of sulphate of copper is decomposed by potassa; by a gentle heat, however, it loses its water, and is converted into the black protoxide.

(2.) *Sulphate of protoxide of copper* (CuO,SO_3), or blue vitriol, with water of crystallization, is one of the most beautiful salts, and is obtained by heating metallic copper with sulphuric acid. It is employed for making many other preparations of copper, and is likewise extensively used for protecting wheat from the depredations of insects, which is done by merely digesting the seed-corn in a solution of the salt.

(3.) *Carbonate of protoxide of copper* (CuO,CO_2) is a bluish-green precipitate, which is formed when a solution of the preceding salt is decomposed by carbonate of soda. This compound, which is employed as a colour, is formed particularly when copper or alloys of this metal are alternately exposed to the influence of water and air, and is commonly termed *verdigris*.

(4.) *Arsenite of protoxide of copper* is the main ingredient of the beautiful Schweinfurt green, which, however, on account of its poisonous properties, is seldom or never used.

Of the *acetate of protoxide of copper*, or the true verdigris, we shall again have occasion to speak.

26. BISMUTH.

Symbol: Bi = 213; Specific Gravity = 9·8; Fusing-point = 246° C. (474°·8 F.).

98. This metal, the colour of which is reddish-white, is neither of frequent occurrence nor is it possessed of properties of any particular value. It may, however, be remarked, that when fused and allowed slowly to cool, it exhibits a remarkable tendency to crystallize. It is employed as a constituent of the fusible alloys (see Tin), and its oxide is used medicinally, and as a white paint.

27. LEAD (PLUMBUM).

Symbol: Pb = 103·7; Specific Gravity = 11·5; Fusing-point = 322° C. (611°·6 F.).

99. Lead is commonly found in combination with sulphur as a grayish white, lustrous mineral called *galena*. When this ore is heated in the atmosphere, or as the workmen term it, roasted, the sulphur is burned with formation of sulphurous acid, whilst the lead unites with oxygen to produce the oxide from which the metal is subsequently prepared by fusion with coal.

This ponderous and soft metal, which admits of being cut with a knife, is familiar to every one; it is rolled into plates and drawn out into tubes, and is, moreover, used for many kinds of casting, amongst which balls and shot are not the least important. It is likewise a constituent of many alloys which will be considered under tin.

100. The compounds of lead are poisonous, and have the effect of producing violent pains in the bowels, termed *lead-colic*, against which the sulphuretted

waters are frequently employed. Poisoning by lead is frequently occasioned by the use of imperfectly-burned earthenware (§ 88), and tin vessels containing lead.

(1.) *Protoxide of lead* (PbO), which is termed also *litharge* or *silver-litharge*, is formed when lead is heated in the atmosphere, and is thus obtained as a waste product in the separation of silver. It consists of small shining plates of yellowish-gray colour, and is employed in the preparation of other compounds of lead, particularly of glass and glazes (§ 75), and of varnishes and plasters. A mixture of the protoxide and binoxide of lead forms the well-known *minium*, or red-lead, which is used as a paint, and for the same purposes as the protoxide.

(2.) *Carbonate of protoxide of lead* (PbO,CO_2), or *white-lead*, is one of the most important colours, and is most simply obtained by passing a stream of carbonic acid into a solution of acetate of lead. It possesses in a high degree the property of imparting *body* to colours, and hence is used as the basis of most other paints. The inferior kinds of white-lead are largely adulterated with heavy-spar (§ 83). The genuine white-lead should dissolve entirely in pure *dilute* nitric acid.

28. TIN.

Symbol: $Sn = 59$; Specific Gravity $= 7 \cdot 3$; Fusing-point $= 228^\circ$ C. ($442^\circ \cdot 4$ F.).

101. Next to silver, tin is the most beautiful of white metals, and on account of its lustre and stability in the atmosphere, is employed in the fabrication of many utensils for the table. It is most frequently met with in combination with oxygen, forming the so-called *tin-stone*, from which the pure metal is obtained by fusion with coal. Occasionally tin contains arsenic, or it is intentionally adulterated with lead, and hence in both cases it is highly dangerous.

This metal is employed in casting, and for preparing *tin-foil* and the spurious *leaf-silver*. It is likewise extensively used for protecting sheet-iron from the oxidizing influence of the atmosphere. The sheets of iron when thus coated, or rather alloyed with tin, constitute the well-known tin-plate which is a highly valuable material, and is employed for numberless purposes. Copper vessels are also *tinned*, and may then be employed without danger for cooking food, as the tin is not in the least degree affected by the materials used in cooking. Some of the tin-alloys have been already described under copper; of the others the most important are:—

(1.) The *solder* of the tinman, which consists of 2 parts of tin and 1 of lead. 2. *Fusible alloy*, formed of 8 parts of bismuth, 5 lead, and 3 tin, fuses at 100° C. (212° F.), and that which consists of 4 parts bismuth, 1 lead, and 1 tin, fuses at so low a temperature as 94° C. ($201^\circ \cdot 2$ F.)

Of the compounds of tin we shall describe:—

(1.) *Protoxide of tin* (SnO), which is formed by heating the metal in contact with the atmosphere, and is principally employed in the preparation of enamel (§ 77), and of the glaze for the Fayence porcelain (§ 88).

(2.) *Protochloride of tin* ($SnCl$) is obtained in colourless crystals when metallic tin is dissolved in hydrochloric acid. In consequence of its property of heightening many colours it has received an important use in the printing of cotton.

(3.) *Sulphide of tin*, which is prepared by gently heating for some time scrapings of tin with sulphur, is a golden-yellow compound of metallic lustre, and is employed as a gold paint under the name of *Mosaic gold*.

29. ZINC.

Symbol: Zn = 32·6; Specific Gravity = 6·8; Fusing-point = 412° C. (753°·6 F.).

102. Zinc is a bluish-white brittle metal, principally obtained from a mineral, known under the name of *calamine*, which is a *silicate of protoxide of zinc*. It is used for castings, and, when rolled into sheets, for covering roofs and many other purposes. As we have already seen it is a constituent of brass and of German silver; and is, moreover, employed by the chemist principally for preparing hydrogen.

The compounds of zinc when taken internally act as poisons, producing a nauseating effect upon the stomach, but several of them, and especially the white *protoxide* (ZnO), and the *sulphate* (ZnO,SO_3), which is also termed white vitriol, are employed with great benefit in many diseases of the eyes.

30. CHROMIUM.

Symbol: Cr = 26·7; Specific Gravity = 5·9.

103. This metal is less generally known than the foregoing, although it is one of the most interesting with which we are acquainted. Almost all its compounds are distinguished by a beautiful colour; and hence it has derived its name from the Greek word χρῶμα, which signifies *colour*.

It is found chiefly in the *chrome iron-stone*, which consists of protoxide of iron and sesquioxide of chromium (Cr_2O_3). By igniting the pulverized mineral with potassa, chromic acid (CrO_3) is formed, and combines with the potassa to produce the *chromate of potassa* (KO,CrO_3), which is a yellow salt, soluble in water, and is employed in making all the other compounds of chromium.

The metal itself, like manganese and pure iron, is extremely difficult to fuse; at present it has received no important application. We shall, therefore, pass at once to the consideration of its compounds.

(1.) *Sesquioxide of chromium* (Cr_2O_3) is obtained in the form of a beautiful green powder, when chromic acid is reduced by gently warming a solution of chromate of potassa with sulphide of potassium. It may be likewise prepared by a variety of other processes, but is always more or less of a fine green colour; it is employed as a pigment, and especially in the painting of glass and porcelain (§ 77).

(2.) *Sesquichloride of chromium* (Cr_2Cl_3) is a crystalline compound occurring in brilliant peach-coloured scales. It has, however, received no application.

(3.) The double salt of *sulphate of sesquioxide of chromium* and *sulphate of potassa* ($Cr_2O_3,3SO_3 + KO,SO_3$) forms beautiful garnet-red crystals. It is termed *chrome-alum*, and is without application.

(4.) On the other hand, the *chromate of lead* (PbO,CrO_3), in its various modifications, is much employed as a yellow pigment, and is obtained on mixing a solution of a lead-salt with chromate of potassa.

(5.) Amongst the numerous other combinations of this metal, which our space will not allow us to describe, the most important is, perhaps, the

chromate of mercury, which is distinguished by its beautiful vermilion-red colour. All the compounds which are soluble produce a poisonous effect upon the animal economy.

31. ANTIMONY (STIBIUM).

Symbol: Sb = 129; Specific Gravity = 6·8; Fusing-point = 425° C. (797° F.).

104. We observe in antimony one of the most brittle metals, since it admits of being readily pulverized. It has a bluish-white colour and fine-grained fracture, and is but little altered on exposure to the atmosphere. An alloy, consisting of one part of this metal and four of lead, is used in type-founding.

The compounds of antimony are remarkable for their medicinal effects, and therefore rank amongst the most important remedial agents. In large quantities they induce sickness, and sometimes act as poisons, but in small doses their effects are powerfully sudorific. The most important of these compounds employed in medicine are the *tartrate* of teroxide of antimony and potassa, which is termed also *tartar-emetic*, and the tersulphide (SbS_3), which occurs native as a black crystalline lustrous mineral, whilst that which is artificially prepared forms a beautiful orange-red powder (§ 43). Antimony likewise combines with more oxygen, producing antimonious acid (SbO_4) and antimonic acid (SbO_5).

32. MERCURY (HYDRARGYRUM).

Symbol: Hg = 100; Specific Gravity = 13·5; Boiling point = 360° C. (680° F.).

105. With this metal we commence the series of the noble metals, which remain unaltered by exposure to the atmosphere.

Mercury exhibits the remarkable property that, whilst it is one of the heaviest bodies, its particles adhere so slightly together that it remains fluid at the ordinary temperature of our atmosphere. Its important application to the barometer and thermometer has been already alluded to in the section Physics.

It possesses, moreover, other properties, which have led to highly-important applications of this metal; amongst these, perhaps, the most remarkable is, its power of overcoming the cohesion of the particles of, and dissolving other metals, producing semi-fluid compounds termed *amalgams*.

Such an amalgam of tin and mercury is employed as a coating for the glass used for mirrors. The amalgam for electrical machines consists of two parts of mercury, one part of tin, and one of zinc. Mercury is likewise indispensable in the *parting* of gold and silver, and in the process of gilding.

This metal is found either native or in combination with sulphur, and is prepared from the latter by mixing it with iron-filings, and submitting it to distillation. It is met with in small quantities in Rhenish Bavaria in Germany, but the chief quantity of that which is met with in commerce is imported from Spain, South America, and more recently it has been imported from China.

106. The *compounds* of mercury generally are powerful poisons, and even the vapours of the metal itself are highly pernicious, inducing, in the first place, a copious flow of saliva. In small doses, however, several of these compounds are employed as remedies which produce remarkable effects upon the organism.

(1.) *Protoxide of mercury* (HgO) is obtained as a brilliant brick-red powder, by igniting the nitrate. It is chiefly employed in preparing oxygen, and in medicine as a constituent of eye-salves.

(2.) *Chloride of mercury* ($HgCl$) is likewise termed *sublimate*, since it is obtained by the sublimation (Physics, § 129) of common salt with sulphate of protoxide of mercury. It is one of the strongest poisons, exerting its destructive power both upon plants and animals. Hence its solution is employed as a preventive against the propagation in timber of a peculiar fungus, known as *dry-rot*, which often makes enormous ravages in wood-work. This process is named, after its discoverer, *Kyanizing*. Sublimate is, moreover, employed as an external remedy for ring-worm and other obstinate diseases of the skin.

(3.) *Subchloride of mercury* (Hg_2Cl), or *calomel*, which is obtained by subliming a mixture of the chloride and metallic mercury, is one of the most frequently employed medicines, acting chiefly as a purgative.

(4.) *Sulphide of mercury*, or *vermilion* (HgS).—We have already several times mentioned this compound, which is known also by the name of *cinnabar*. Although this beautiful crimson colour occurs in Nature ready formed, it is, nevertheless, artificially prepared by subliming one part of sulphur with six parts of mercury, and subsequently triturating the mass obtained to an impalpable powder. A very magnificent kind of cinnabar is prepared by the Chinese.

§ 33. SILVER (ARGENTUM).

Symbol: $Ag = 108 \cdot 1$; Specific Gravity = 10; Fusing point = 1000° C. (1832° F.).

107. Silver, although it is not the most costly, is, nevertheless, one of the most beautiful metals, and the bright lustre of plate, and the numberless objects into which it is worked, universally excite our admiration; it is, moreover, exceedingly malleable and ductile, and admits of being wrought into the most beautiful works of art, and drawn out into thin wires; it is also the best known conductor of heat and electricity.

Silver is found in the metallic state, and frequently alloyed with lead, as in the argentiferous galena. From this ore the silver is prepared by roasting in a smelting furnace, whereby the lead is volatilized in the form of oxide, whilst the pure silver remains behind.

In some countries, as in Saxony and South America, recourse is had to another process, that of amalgamation, which depends on the easy solubility of silver and other metals in mercury. The ore, after being reduced to a fine powder, is mixed with common salt, and roasted at a low red-heat, whereby any sulphide of silver the ore may contain is converted into chloride. The mixture is then placed, with some water and iron filings, in a barrel which revolves round its axis, and the whole agitated for some time, during which process the chloride of silver becomes reduced to the metallic state. A portion of mercury is then introduced, and the agitation continued. The mercury combines with the silver, and the amalgam is then separated by washing. It is afterwards pressed in woollen bags to free it from the greater part of the mercury, and then heated, when the last trace of mercury volatilizes and leaves the silver behind.

108. *Nitrate of silver* (AgO,NO_5) is obtained in splendid white crystals when metallic silver is dissolved in nitric acid. It acts as a powerful caustic,

readily destroying the animal tissues, and is extensively employed in surgery, as an external remedy, under the name of *lunar caustic.* When in contact with soluble organic substances it communicates to them, after a short time, a black colour, which is due to the reduction of a portion of the silver; hence it is employed as the basis of the indelible inks used for marking white linen.

Chloride of silver ($AgCl$). When to a solution of silver is added chlorine, or any chlorinated compound, we obtain this compound as a white precipitate, which, on exposure to the light of the sun, speedily acquires a violet colour, which finally passes to black. The *iodide of silver* is even more rapidly altered by light; to this, however, we shall again have to return.

34. GOLD (AURUM).

Symbol: $Au = 197$; Specific Gravity $= 19 \cdot 5$; Fusing point $= 1200^\circ$ C. (2192° F.).

109. Gold is the most beautiful of all the metals, and by the ancients was termed the sun, or the king of metals. It appears to be pretty generally diffused in Nature, but never occurs in large masses, and hence it is also of higher value than any of the other metals. It is most frequently found in South America, California, Australia, East Indies, Africa, Hungary, and in the Ural Mountains. In general it is met with in the metallic state, partly in large fragments, but more frequently disseminated in small grains through various rocks. From the disintegration of these rocks is derived the gold-sands of many rivers, and from which the gold, on account of its high specific gravity, is readily separated by washing. But from poor ores it is generally obtained by amalgamation with mercury, which dissolves the gold, and which is afterwards separated by distillation, when the mercury is volatilized, and the pure gold remains behind.

The most remarkable property of gold is its extreme ductility. A single grain may be drawn into a wire 500 feet in length. It allows of being beaten into leaves which scarcely exceed $\frac{1}{200000}$ of an inch in thickness. It is, therefore, employed for gilding a great variety of objects, the process being effected either by coating them with the leaf-gold, as in the case of picture-frames, or by painting the metallic objects with a solution of gold in mercury, and subsequently exposing them to a high temperature whereby the mercury is volatilized. Objects of art are also frequently coated with gold by the electrotype process (§ 113).

With regard to the chemical properties of gold, it may be remarked that it is attacked by none of the individual acids; it is, however, dissolved by free chlorine. To obtain this metal in solution it is usual to employ a mixture of nitric and hydrochloric acids (§ 36), which is known under the name of *aqua regia.*

This metal being pretty soft and very costly, is never employed in the pure state. For coins and objects of art it is usually alloyed with silver or copper, which impart to it considerable hardness.

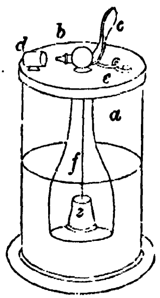
35. PLATINUM.

Symbol: $Pt = 98 \cdot 7$; Specific Gravity $= 21$.

110. This metal has been known only since the discovery of America, and the greater part occurring in commerce was exclusively imported from the

Southern portions of this Continent, until within the present century it was found in the Ural Mountains. It is invariably met with in the metallic state of a whitish-gray colour; it is, moreover, pretty soft and highly ductile, and, like gold, is only attacked by free chlorine, which in the form of *aqua regia* readily dissolves it. It is distinguished from gold by being infusible in the strongest fires, a property which renders it a highly-valuable material in the fabrication of many chemical vessels, such as crucibles, dishes, &c. As we have already seen (§ 41), the stills employed in the rectification of sulphuric acid are made of this metal, and sometimes cost from one to two thousand pounds. In Russia, platinum is coined into money; but the infusibility of this metal renders it extremely difficult to work.

In the finely-divided state it forms a gray and very porous mass, which is known as *spongy platinum*, and possesses the remarkable property of condensing gases within its pores. Hence, when a jet of hydrogen is directed upon a piece of spongy platinum, the heat caused by its condensation suffices to inflame the gas. This singular power has been applied to the construction of a very beautiful apparatus, known as Döbereiner's lamp (fig. 40), which consists of a glass jar *a*, covered by a brass lid *e*, which is furnished with a suitable stop-cock *c*, and in connection with a small bell-jar *f*, in which is suspended, by means of a wire, a cylinder of metallic zinc *z*. When required for use, the outer jar is two-thirds filled with a mixture of one part sulphuric acid and four parts water, and the stop-cock opened to allow the escape of atmospheric air, the spongy platinum contained in the small brass cylinder *d* being covered by a piece of paper. The stop-cock is then closed, and the bell-jar *f* allowed to fill with hydrogen, and after it has been filled and emptied several times, the paper is removed from the platinum and the cock is again opened, when the gas, which escapes first, makes the metal red-hot, and finally inflames.



40.

II. Peculiar Decompositions of Simple Chemical Groups.

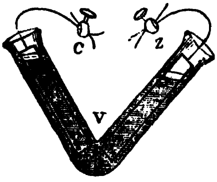
(1.) DECOMPOSITION BY ELECTRICITY.

111. When an electrical current (Phys. § 186) is passed through a liquid chemical compound, a decomposition is found to take place, if the stream is sufficiently powerful, and providing the two electrodes are not placed too far from each other. In decompositions of this nature we observe the peculiarity that one constituent of the compound is evolved at the *positive pole*, whilst the other appears at the *negative pole*. Hence the former is termed the *electro-negative*, and the latter the *electro-positive* of the compound.

If the electrodes are constructed of a metal possessing the property of combining with the evolved bodies, we observe that such an union takes place, as when the wires are made of copper and an oxygen compound is decomposed, the oxygen unites with the copper to form the protoxide of this metal. Hence the conducting wires are generally made of platinum, a metal which is affected only by a few bodies.

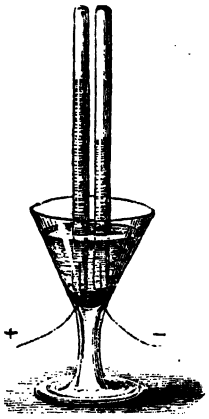
In the decomposition of salts, the acid makes its appearance at the + pole and the base at the − pole. If, therefore, a solution of sulphate of soda

(NaO,SO_3), coloured blue by a little infusion of violets or blue cabbage, is introduced into the V tube, fig. 41, and a stream of electricity is passed into it by the two wires *c*, *z*, the sulphuric acid is liberated at the + pole, and colours the liquid in that branch of the tube red, whilst in the other branch the liquid is coloured green by the soda, which is set free at the − pole. As soon as the current is interrupted, the acid again combines with the base, and the liquid thus rendered neutral regains its blue colour (comp. § 17).



41.

If the two inverted tubes, fig. 42, be filled with water, and a powerful current of electricity passed through them, the water is decomposed, and we obtain in the one tube oxygen, and in the other a double volume of hydrogen (§ 28).



42.

112. With regard to the elements already known to us, it may be remarked, that under all circumstances oxygen is eliminated at the + pole, and potassium at the − pole. The other simple bodies, however, sometimes appear at the one pole, and sometimes at the other.

In the following *electrical* series, the elements are so arranged that each substance deports itself electro-negatively towards those which follow, and electro-positively to those which precede it. As, for example, chlorine when in combination with oxygen, is evolved at the − pole, and from its compound with hydrogen, at the + pole. Those elements, which in this series are placed farthest apart, have stronger opposite affinities than those which are nearer to each other.

Electrical Series of the Elements.

− Oxygen,	Carbon,	Copper,	Aluminum,
Sulphur,	Chromium,	Bismuth,	Magnesium,
Nitrogen,	Boron,	Lead,	Calcium,
Chlorine,	Antimony,	Cobalt,	Strontium,
Bromine,	Silicium,	Nickel,	Barium,
Iodine,	Gold,	Iron,	Sodium,
Fluorine,	Platinum,	Zinc,	+ Potassium.
Phosphorus,	Mercury,	Hydrogen,	
Arsenic,	Silver,	Manganese.	

The importance of these facts to science is unmistakeable, and, indeed, many attempts have been made to explain, from the electrical condition of the elements, the nature of chemical affinity, and of chemical phenomena in general.

The Electrotype Process.

113. This is one of the most beautiful applications of decomposition by the electric stream. A solution of a metallic oxide, such as sulphate of *protoxide of copper*, when submitted to the influence of the electric current is decomposed, the oxygen being separated at the positive, and the copper at the negative, pole. But as metals do not readily combine with each other, the copper in this instance forms a coating upon the surface of the electrode. It

is, however, perfectly indifferent what form we give to the pole, so that it may terminate either in a wire, a ball, or a plate with a plane or a partly convex and concave surface; the coating of copper thus deposited by the electric current necessarily assumes the form of the corresponding pole. By this process, then, the most accurate casts of medals, engraved copper plates, &c., may be prepared.

Gilding and *silvering* by the galvanic process depend upon the same principles. But in this case a solution of gold or silver is introduced into the liquid, and the object to be gilt forms itself the negative pole on which the liberated noble metal becomes deposited.

2. DECOMPOSITION BY LIGHT.

114. In addition to its luminous properties, the light of the sun manifests an important influence, especially upon chemical affinity and the vital power. We have already seen (§ 22) that the leaves of plants evolve oxygen only when exposed to the solar rays; and that chlorine and hydrogen (§ 36) do not combine unless subjected to the same influence. In the section Physics (§ 88) we have defined light as the vibration of æther; and we perceive therein a certain means of exciting the activity of material particles, of which, however, we cannot form a clear conception, nor can we prove it by experimental evidence.

Daguerreotype Process.

The beautiful daguerreotype portraits, or photographic pictures, which are obtained by the decomposition of chemical compounds by solar light, have of late acquired considerable celebrity. The process may be explained as follows:—

Iodide of silver is a compound which is highly susceptible of the influence of light. For daguerreotype experiments it is most conveniently obtained by exposing a polished plate of silver to the vapour of iodine until it becomes covered with a pale yellow film of iodide of silver. As is well known (Phys. § 143), the lighter-coloured bodies, or lighter parts of bodies, reflect more light-rays than darker substances. If, therefore, the iodized silver-plate be introduced into a camera obscura, and the image of an object produced by a compound lens be allowed to fall upon it, the iodine will be separated from the silver on those parts of the plate upon which the light-rays from the object fall. This decomposition is effected more rapidly and completely upon those parts where most light falls. In a few seconds this decomposition is completed; it is not, however, sufficient to produce a distinct picture. The plate, therefore, is afterwards exposed to the vapours of mercury, which amalgamate with those parts of the surface which are freed from iodine, and thus the picture is developed. The plate is then immersed in a saline solution, which removes the excess of iodide of silver, and thus prevents any further action of the light upon the plate. Daguerreotype pictures consist of a dark ground, upon which, in certain places, minute bright globules of mercury are deposited. The picture, however, in this state may be readily rubbed out, and in order to protect it from injury, it is coated by the galvanic process with an exceedingly thin film of gold, and afterwards put in a frame and glass.

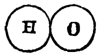
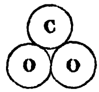
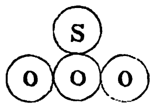
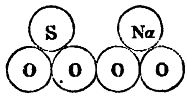
The discovery of this process, which gives pictures of wonderful fidelity, was made in Paris in 1839, by *Daguerre*, who received from the French nation a handsome recompense for his labours.

(B.) COMBINATIONS OF THE COMPOUND GROUPS.

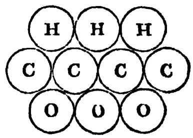
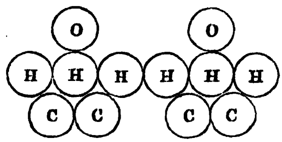
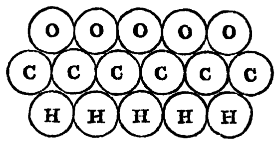
(ORGANIC CHEMISTRY.)

115. As we have already shown at § 13, the compounds now to be considered differ very materially from those hitherto described. This becomes at once evident by a comparison of the individual formulæ which the simple and compound groups of chemical compounds present to us.

SIMPLE GROUPS.

	Formulæ.	
Water - - - - - - - =	HO	
Carbonic Acid - - - - =	CO_2	
Sulphuric Acid - - - - =	SO_3	
Sulphate of Soda - - - - - -	NaO, SO_3	

COMPOUND GROUPS.

	Formulæ.	
Acetic Acid (Anhydrous) - =	$C_4H_3O_3$	
Spirit of Wine - - - - =	$C_4H_6O_2$	
Sugar (Anhydrous) - - =	$C_6H_5O_5$	

From this it will be seen that a water-equivalent is a group of two individual particles, an equivalent of sulphuric acid of four, and that an equivalent of sulphate of soda consists of six particles. On the other hand, an equivalent of acetic acid is formed of ten individual particles, an equivalent of sugar of sixteen, and many other substances occur which are composed of even a still larger number of particles.

It would be impossible for us here to elucidate the reasons which have led chemists to the conviction that these compounds actually consist of such complex groups of simple particles. It will suffice to mention that all past experience leads to such a conviction.

116. In reference to the compounds of these complex groups, we have arrived at the following general facts:—

(1.) The elements which combine together to produce these compounds are—*carbon*, *hydrogen*, *oxygen*, *nitrogen*, *sulphur*, and *phosphorus*. Some compound bodies consist of two of these elements, namely, of carbon and hydrogen, but the greater number contains three—carbon, hydrogen, and oxygen; a large number consists of four—carbon, hydrogen, oxygen, and nitrogen; and only a few contain five or six, including, with the last-mentioned elements, sulphur and phosphorus. Many organic compounds, which are however comparatively of less importance, contain, in addition to the above-mentioned elements, chlorine, bromine, iodine, arsenic, antimony, &c.; hence we may assume that every element may occur as a constituent of organic compounds. It will be remarked that carbon is an invariable constituent of all these combinations.

(2.) The great multiplicity of these combinations arises from the fact that, generally *several* equivalents of each of these simple bodies unite together, as has already been shown in the case of acetic acid, spirit of wine, and sugar.

(3.) It is difficult and in most cases impossible to unite such a great number of equivalents of simple bodies by merely bringing them into contact. In the vegetable and animal organisms, however, the elements are, by the co-operation of several forces, placed in such favourable circumstances, that they combine to produce an extensive series of chemical compounds, which are called, in reference to their origin, *organic* compounds.

(4.) Under the influence of a variety of causes, such as heat, light, electricity, chemical affinity, and frequently even mechanical action, the organic combinations are destroyed and separated into more simple compounds. Thus, for instance, anhydrous grape-sugar ($C_6H_6O_6$) is easily split into alcohol ($C_4H_6O_2$) and carbonic acid ($2CO_2$). The property of passing through entire series of metamorphoses is characteristic of organic compounds.

(5.) In almost every complex organic combination, we are able to prove the existence of a more simple compound of greater stability which is generally termed the *radical* of the combination. The nature of these radicals will be subsequently described.

(6.) Finally, if we carefully consider the simple substances, detailed in (1.), which enter into the composition of organized bodies, we cannot overlook the fact that with oxygen they may all form gaseous combinations. If, therefore, an organic body be ignited with access of air, it is *completely consumed, and generally after it has been converted into a black carbonaceous mass.* This property of blackening, which is due to the presence of carbon, is a sure characteristic of an organic compound.

(7.) Those organic bodies which consist only of carbon, oxygen, and hydrogen, are easily distinguished from those which contain also nitrogen or nitrogen and sulphur. The presence of these two latter constituents may be recognised in the spontaneous decomposition or dry distillation of the organic bodies, by the offensive odour of the products evolved. These products consist chiefly of ammonia and hydrosulphuric acid. Hence any nitrogenous substance may be detected by burning it; it then disengages vapours which have the odour of burnt hairs or feathers; or the substance under examination may be heated with hydrate of lime, when, if nitrogen be present, a distinct odour of ammonia will be evolved.

1. Compound Radicals and their Combinations.

117. By the reaction of several substances upon alcohol we are enabled to obtain an entire series of combinations, which, in reference to their composition, stand in a remarkable relation to each other, as well as to the alcohol from which they are derived. We must here confine ourselves to the names and formulæ of these substances, the greater number of which possess merely a scientific interest; only a few of them being employed in medicine.

Name.	Composition.
Alcohol - - - - - -	$C_4H_5O; HO$
Ether - - - - - - -	C_4H_5O
Chloride of Ethyl - - -	C_4H_5Cl
Bromide of Ethyl - - -	C_4H_5Br
Iodide of Ethyl - - -	C_4H_5I
Sulphide of Ethyl - -	C_4H_5S
Carbonate of Ethyl - -	C_4H_5O, CO_2
Oxalate of Ethyl - - -	C_4H_5O, C_2O_3
Nitrite of Ethyl - - -	C_4H_5O, NO_3

It will be observed, that in this series, the number of equivalents of carbon and hydrogen is the same in all these combinations, with the exception of the alcohol itself. This leads to the assumption that, in all the above-mentioned substances, there exists a combination, C_4H_5, which presents, in its chemical behaviour, the greatest similarity to a simple body. This compound has, therefore, been considered as the *radical* of the series and is termed *ethyl*, for which the symbol *Ae* has been adopted.

Let us once more examine this series and notice how it presents itself after the introduction of *Ae* instead of C_4H_5. To assist the comparison we will write, in juxtaposition, a corresponding series of the combinations of a simple body:—

Compound Radical.	Simple Radical.
C_4H_5 = Ae = Ethyl	K = Potassium
Ae + O = Oxide of Ethyl (Ether)	K + O = Oxide of Potassium (Potassa)
Ae + Cl = Chloride of Ethyl	K + Cl = Chloride of Potassium
Ae + I = Iodide of Ethyl	K + I = Iodide of Potassium
Ae + Br = Bromide of Ethyl	K + Br = Bromide of Potassium
Ae + S = Sulphide of Ethyl	K + S = Sulphide of Potassium
Ae O + HO = Hydrate of Oxide of Ethyl (Alcohol)	KO + HO = Hydrate of Oxide of Potassium (Potassa)
Ae O + CO_2 = Carbonate of Ethyl	KO + CO_2 = Carbonate of Potassa
Ae O + C_2O_3 = Oxalate of Ethyl	KO + C_2O_3 = Oxalate of Potassa
Ae O + NO_3 = Nitrite of Ethyl	KO + NO_3 = Nitrite of Potassa

The opinion, that this series of combinations is produced by other simple and compound bodies combining with the compound organic radical ethyl, has been strengthened by the fact, that also in acetic acid, benzoic acid, formic acid, fusel-oil, and several other organic combinations, we have proved the existence of such radicals which give rise to series of combinations perfectly analogous to those of the radical above mentioned.

Although it is the object of many chemical investigations made at the present day to discover in all organic combinations the corresponding radicals, still there are many organic substances of great importance, the radicals of which have not yet been discovered.

We can here only allude to these remarkable relations. In the following pages we shall, without regard to theoretical opinions, classify the organic combinations, according to their general chemical properties, into *acids*, *bases*, and *indifferent bodies*.

(I.) ACIDS.

118. The organic acids are mostly contained in the sap or in particular parts of plants, and especially in fruits. Without being corrosive, they have a pure acid taste, and none, with the exception of oxalic acid, exerts a poisonous influence on the animal economy. All these acids possess a feebler affinity than sulphuric acid, and are, therefore, separated by this acid from the bases with which they may be combined. They are either volatile or non-volatile, and are usually prepared by saturating the liquids containing them with lime, evaporating the solution of the *lime-salt* thus obtained to dryness, and subsequently decomposing it by sulphuric acid, when the organic acid which is thus liberated is either distilled off or separated by filtration.

Another common mode of preparing the non-volatile acids is to combine the acid with protoxide of lead, and to decompose an aqueous solution of the lead-salt by hydrosulphuric acid. In this manner we obtain an insoluble precipitate of black sulphide of lead, whilst the acid is held in solution in the water, and is obtained by filtration in a state of purity. Of the large number of organic acids, we shall describe only the most important—namely, acetic, tartaric, citric, malic, oxalic, tannic, formic, lactic, and the fatty acids.

1. ACETIC ACID.

Formula = $C_4 H_3 O_3$; Symbol = $\bar{A}$.

119. Only a limited number of vegetable juices in their natural condition contain acetic acid; it is, however, readily formed when spirit of wine, or vegetable juices capable of undergoing alcoholic fermentation, is exposed, under certain circumstances, to the influence of the atmosphere, or when vegetable matter, especially wood, is submitted to dry distillation. Both these processes will be more minutely described farther on.

The purest and most concentrated acetic acid forms at 5° C. (41° F.) beautiful transparent crystals, which, however, liquify at a temperature of 16° C. (60·8° F.). When dissolved in a large quantity of water, they have an agreeably refreshing odour and taste, and hence are frequently used at table as vinegar. Of the salts of this acid we shall mention only the following:—

Acetate of protoxide of lead ($PbO,\bar{A}$). This salt is obtained by dissolving oxide of lead in strong vinegar, and crystallizing the salt which is thus formed.

It has a sweetish taste, and is, therefore, termed *sugar of lead.* The solubility of this salt in water renders it peculiarly adapted to the preparation of most of the other compounds of lead, such as the chrome-yellow and white-lead (§ 99), and, therefore, to the purposes of dyeing. A solution of sugar of lead is employed in medicine as an external remedy, under the name of *Goulard's Extract*, and when more diluted it forms the well-known *Goulard's water.* An addition of sugar of lead promotes, in a high degree, the drying of oil-colours. Acetate of lead is, moreover, a powerful poison.

Acetate of copper ($2CuO,\bar{A}$), commonly called *verdigris*, is produced by placing sheets of copper in contact with acetic acid. It has a bluish-green colour and is likewise poisonous.

Acetate of potassa and *acetate of ammonia* are very frequently employed in medicine, particularly for promoting the healthy functions of the skin.

2. TARTARIC ACID.

Formula = $C_8\,H_4\,O_{10}$; Symbol = $\bar{T}$.

120. This acid is contained especially in the juice of the grape, and when perfectly pure it forms colourless tabular crystals of strongly acid taste. Its most important compound is the *bitartrate of potassa* ($KO, HO, \bar{T}$), which is deposited as an incrustation upon the bottoms of casks in which new wine is stored. The purified salt is beautifully white, and its powder is employed in medicine under the name of *cream of tartar.* In dyeing it is frequently used as a mordant. The double salt of tartrate of potassa and tartrate of teroxide of antimony, called *tartar-emetic*, is much employed as an emetic.

3. CITRIC ACID.

Formula = $C_{12}\,H_5\,O_{11}$; Symbol = $\bar{C}$.

121. Citric acid is found in the free state, chiefly in the citron and lemon, and also in gooseberries, currants, and other fruits. It is distinguished by an agreeably acid taste; it forms columnar crystals, which, like the preceding, are frequently employed in dyeing.

4. MALIC ACID.

Formula = $C_4\,H_2\,O_4$; Symbol = $\bar{M}$.

122. This acid is contained in almost all fruits, particularly in apples, and most abundantly in the berries of the mountain-ash, from which it is commonly prepared. It is crystallizable and highly acid, but is without application.

5. OXALIC ACID.

Formula = $C_2\,O_3$; Symbol = $\bar{O}$.

123. The saps of common sorrel and of wood-sorrel contain *oxalate of potassa* ($KO, 2\bar{O}$), which is obtained from these vegetable juices in colourless crystals, and is commonly called *salt of sorrel.* This salt, as well as the acid itself, forms a readily-soluble compound with the oxide of iron, and hence its frequent application for removing spots of ink; it is likewise used in dyeing. We may remark that this acid is artificially prepared in large quantities by gently heating sugar with nitric acid. In consequence of its simple constitution it may be also arranged with the simple groups. The acid and its soluble salts are poisonous.

6. TANNIC ACID.

Formula = $C_9 H_3 O_5$; Symbol = $\bar{Q}t$.

124. This acid is diffused to a great extent throughout the vegetable kingdom, and we may assume that all vegetable matters which possess an astringent taste contain tannic acid. It occurs, however, most abundantly in the bark of the oak, and in gall-nuts. When prepared from these substances it forms a yellowish powder of highly astringent taste. Its acid properties are very feeble. In medicine it is employed as an astringent, both internally and externally, especially for arresting hæmorrhage, &c.

The most remarkable property of tannic acid is that of producing with the oxides of iron a deep violet or black compound, which under the name of *ink* is, incontestably, one of the most important requisites of the present age.

Ink is prepared by boiling together, for some time, 3 oz. of bruised galls and 1 oz. of sulphate of iron, with 2 or 3 pints of water, to which is then added 1 oz. of log-wood, and finally, 1½ oz. of gum-arabic, for the purpose of rendering it somewhat thicker. A similar solution is employed for dyeing various kinds of cloths of a black, gray, or violet colour. If we desire to ascertain whether a liquid, as for instance water, contains iron, we macerate a gall-nut in water or brandy, and add a few drops of the tincture thus prepared to the water, which instantly becomes of a violet colour, if it contains only a trace of iron. If fruit be cut with a knife a portion of the iron becomes dissolved by the acids always present, and subsequently combines with the tannic acid, contained principally in the rind, and appears as a blue or black coloured compound. Wine, which contains tannic acid, when mixed with a chalybeate water, likewise imparts a violet colour to the mixture.

Tannic acid has derived its name from the property it possesses of forming with hides, a compound which is insoluble in water, and commonly known as *leather*, hence it is an essential requisite in the process of tanning, which we shall describe farther on.

7. FORMIC ACID.

Formula = $C_2 HO_3$; Symbol = $\dot{F}$.

125. Ants contain a somewhat caustic acid, which may be used by these small insects as an important weapon of defence. The properties of this acid, however, have been accurately known only since the discovery of a mode of artificially preparing it by the distillation of a mixture of sugar, binoxide of manganese, and sulphuric acid. In the concentrated state, formic acid is a colourless volatile liquid of penetrating odour and caustic properties, for when placed upon the skin it almost instantly raises a blister similar to that produced by burning.

8. LACTIC ACID.

Formula = $C_6 H_5 O_5$; Symbol = $\bar{L}$.

126. Lactic acid is present in many vegetable and animal substances, partly already formed, and partly only subsequently produced by the process of decomposition. Fresh meat invariably presents a feebly-acid reaction, due to the presence of a minute quantity of lactic acid which the juice always contains. It is met with in urine, and as a product of decomposition in sour milk, in the juice of sourkraut, and other pickles, such as ghirkins, &c. It is uncrystallizable,

and has a strongly acid taste; at present it is applied to no particular purpose. The efficiency, however, of sour whey, in removing stains from table-cloths, is due to this acid.

9. FATTY ACIDS.

127. These acids will be more minutely considered when we speak of their natural compounds called *fats*, which comport themselves as indifferent bodies.

(2.) BASES.

128. Certain vegetable substances, by their singularly bitter taste and remarkable effects upon the animal system, have from an early period excited attention, and have claimed the character of valuable remedial agents. We may mention as examples the quina-bark and opium. Recent investigations have shown, however, that not the entire mass of these substances possesses the same medicinal qualities, but that the greater part of them consist of inefficacious substances, such as woody fibre, resin, gum, &c., whilst the peculiar active constituent forms only a very minute share of their weight.

A German chemist of the name of Sertürner, in 1804, was the first who succeeded in extracting the active principle from opium. Shortly afterwards similar substances were discovered in other plants, and when prepared in the pure state it was observed that they comport themselves as *bases*, and produce, with acids, fine colourless and distinctly-crystallizable salts. All the vegetable bases contain nitrogen, and in general possess the following properties:—They are colourless and odourless, but of extremely bitter taste. In water they are insoluble, but on the other hand are soluble in spirit of wine, and many also in ether. Even in very small doses they produce a powerful effect upon the systems of plants and animals, the greater part of them being potent poisons. They are employed exclusively in medicine, to which they have proved of the greatest importance. Whilst formerly it was necessary in ague and other diseases of an intermittent character to take many ounces of pulverized quina-bark to effect a cure, it is now only requisite to take a few grains of quinine to eradicate the same disease. By the use of quinine, moreover, we gain another advantage, namely, we avoid the above-mentioned vegetable matters, which not unfrequently destroy the effects of the base. For example, the quina-bark contains a large quantity of astringent tannic acid, and opium a variety of principles which render the application of it impossible where its base may be administered with great advantage.

The vegetable bases are usually prepared in the following manner:—The parts of plants which contain them are boiled with water, containing an admixture of sulphuric acid. In this manner is obtained a soluble sulphate of the base, which is decomposed by the addition of ammonia. The latter produces with the sulphuric acid a soluble sulphate of ammonia, while the base is precipitated. The base, which is generally somewhat coloured, is redissolved in dilute sulphuric acid, boiled with animal charcoal, and again precipitated by ammonia; the operation being repeated until the base is perfectly colourless. From many substances the bases are extracted by boiling alcohol, decolorized by animal charcoal, and purified by crystallization. Simple as this process may appear, it nevertheless presents many difficulties in practice, especially as

regards the removal of colouring matters, and it requires much care and experience.

The most important organic bases are the following:—

Quinine (formula $C_{20}H_{12}NO_2$) is contained in the different kinds of quina-bark, and, as above mentioned, is employed as an active remedy in febrile diseases. 100 parts of the best bark yield approximatively 3 parts of quinine.

Morphine (formula $C_{35}H_{20}NO_6$) is the active and highly-poisonous base of opium. 100 parts of opium yield about 12 parts of morphine.

Strychnine (formula $C_{44}H_{22}N_2O_4$) is found in several poisonous fruits and barks of trees growing in South America, particularly of the nux-vomica (*Strychnos nux-vomica*), from which it is usually prepared. It is one of the most powerful poisons, of which a few grains are capable of destroying life, its action being characterised by a powerful influence on the spinal marrow.

Coneine (formula $C_{16}H_{15}N$), which is prepared from the hemlock (*Conium maculatum*), is distinguished from the foregoing bases by being fluid and volatile. Its action is highly poisonous, whilst it instantly paralyses the activity of the spinal marrow.

The great importance and the high commercial value of the organic bases, several of which, as quinine and morphine, are endowed with remarkable medicinal properties, have induced chemists to attempt the artificial formation of these compounds, hitherto exclusively produced by vital processes. These endeavours have not as yet been crowned with success; but even now they have elicited a series of very important results, which clearly show that the progress of chemical science cannot fail to solve the problem. From these results it appears that a very close connection may be traced between the organic bases, all of which contain nitrogen and ammonia, which we have considered in a former part of this work (§ 78). We there stated that ammonia consists of one equivalent of nitrogen and three equivalents of hydrogen, and that its composition may be represented by the formula NH_3. Now it has been proved that the various hydrogen-equivalents may be replaced, atom for atom, by various hydrocarbons obtained from very different sources. In the new substances thus produced, the fundamental character of ammonia, namely, its power of combining with acids, is retained. In this manner, by gradually removing the various atoms of hydrogen from ammonia and replacing them by a hydrocarbon C_4H_5 which is called *ethyl*, because, as we have seen, it forms part of ordinary ether, the following series of organic bases or compound ammonias have been obtained:—

Ammonia.	Ethyl-Ammonia.	Diethyl-Ammonia.	Triethyl-Ammonia.
$\left.\begin{matrix} H \\ H \\ H \end{matrix}\right\} N$	$\left.\begin{matrix} C_4H_5 \\ H \\ H \end{matrix}\right\} N$	$\left.\begin{matrix} C_4H_5 \\ C_4H_5 \\ H \end{matrix}\right\} N$	$\left.\begin{matrix} C_4H_5 \\ C_4H_5 \\ C_4H_5 \end{matrix}\right\} N$

All these substances are volatile, like ammonia itself, and differ in this respect from quinine, morphine, &c., which are of a fixed nature. However, Dr. Hofmann, to whom most of these results are due, has lately discovered a series of analogous bodies, still closely connected with ammonia, but which like most of the natural bases have ceased to be volatile. The latter class of substances is likely to become of particular importance; they exhibit the most remarkable properties, several of them combining, in fact, the bitterness of

quinine with the causticity of potassa and soda. These compounds may, probably, be themselves endowed with valuable medicinal properties; at all events they appear to pave the way to the artificial formation of the natural alkaloids.

(3.) INDIFFERENT SUBSTANCES.

129. As these bodies have neither acid nor basic properties, and cannot be compared to the salts, they are termed *indifferent* substances. They are of great importance, both in the arts and in medicine, and are indispensable to the existence of man and animals, since they compose the principal part of animal nutriment. We divide the indifferent substances into those which contain no nitrogen, and those in which this element is present. The latter generally contain also sulphur.

a. NON-NITROGENOUS INDIFFERENT SUBSTANCES.

130. We may assume that these substances, which constitute the principal part of the food of men and animals, contribute but little to the direct increase of the body, but are rather to be regarded as the means of maintaining the natural warmth—in fact, as a sort of fuel, and as the material whereby respiration is supported: to this we shall farther allude in our chapter on nutrition.

While we pass over a large number of the less important compounds, we shall consider only the following more minutely, viz.: starch, gum, sugar, spirit of wine, ether, fats, ethereal oils, resins, gum-resins, colouring matters, woody-fibre, vegetable mucilage, and gelatin.

1. STARCH.

Formula = $C_{12}\,H_{10}\,O_{10}$.

131. Starch is contained in many parts of plants, particularly in the seeds of the cereals, in many tuberous roots, such as those of the potato, dahlia, artichoke, &c., in the pith of the palm, in many fruits, as in apples, and in smaller quantities, even in the bark and wood of trees.

If these parts of plants be ground and agitated with water the starch is separated as a white deposit, which is purified by repeatedly washing; it is then subsequently dried.

Starch is insoluble in cold water and in spirit of wine; but in hot water it swells up into a gelatinous mass, which is known as paste. In a large quantity of hot water it perfectly dissolves. Although little qualified to combine with other substances, it nevertheless forms with iodine a remarkable compound of deep-violet colour. This colour is so remarkable that the minutest trace of iodine may be detected by means of starch, and *vice versâ*.

Starch is employed as food, as a paste, for thickening the colours in calico printing, for stiffening linen cloth, for sizing paper, &c. Several kinds of starch are distinguished according to the plant from which they are derived, such as *potato-starch*, *wheat-starch*, *sago* (from the pith of the palm), *arrow-root* (from the root of Maranta arundinacea), and *tapioca*, which is likewise obtained from an American root. All these kinds of starch, however, agree perfectly with each other in their essential properties.

Starch has derived considerable importance from its products of decomposition: when gently heated, or rather roasted, it is in part converted into a kind

of gum, which is termed *leucom*, and is employed in calico printing. For the same purposes is used the starch-gum or *dextrin*, which is formed when starch is moistened and heated for some time with very dilute sulphuric acid; it possesses almost all the properties of gum-arabic. If the action of the acid upon the starch be continued longer it is finally converted into *starch*, or *grape-sugar*, which has a sweetish taste, but is not crystallizable. As a remarkable fact it may be mentioned that germinated corn contains a substance, termed *diastase*, which has the property of transforming starch into gum and sugar, in the same manner as we effect the transformation by the aid of sulphuric acid (see § 155).

2. GUM.

Formula = $C_{12} H_{11} O_{11}$.

132. Although gum is found in numerous plants, still it is obtained only from a few Eastern trees belonging to the family of Mimosa, and from which it flows in drops that harden in the air, and are generally known under the name of *gum-arabic*. The purest gum is colourless, soluble in water, and insoluble in spirit of wine. It is chiefly employed for pasting, for mixing with colours, lacquering, &c.; it is, however, now frequently replaced by starch-gum, which possesses nearly all its properties. It must be remarked that also other vegetable juices are termed gum; but, in a chemical point of view, we understand by this term only the compound here described.

3. SUGAR.

Formula = $C_{12} H_{11} O_{11}$.

133. Sugar is diffused to a great extent throughout the vegetable kingdom. The greater number of fruits, many roots, and stalks, contain sugar; but it is the small quantity in which it is present, or its admixture with other substances, which prevents, in general, its extraction. It is found, however, most abundantly, and in the purest condition, in the juice of the sugar-cane, in beet-root, and in a species of maple (*Acer saccharinus*). In the sugar plantations of the East and West Indies the canes are crushed and pressed, and the juice, containing about 10 per cent of sugar, mixed with some milk of lime; after being heated, it is allowed to get clear by standing, and then evaporated as quickly as possible, in order to avoid fermentation. The addition of lime is made for the purpose of removing the albumin and vegetable acids of the juice. In this manner is obtained *raw sugar*, which, according to the care displayed in the operation, presents the appearance of a yellowish or brownish moist powder, possessing at the same time a somewhat unpleasant odour and taste. This, which is caused by the impurities of the sugar, is afterwards removed by the process of *refining*, which is generally performed in Europe.

The colour of raw sugar is due partly to the presence of colouring matters, and partly to the conversion of a portion of the sugar during evaporation into a brown-coloured, non-crystallizable kind of sugar, which is termed *molasses*. The sugar is, therefore, dissolved in the smallest possible quantity of water, and boiled for some time with animal charcoal (bone-black, § 51), being thus almost perfectly decolorized. The syrup is afterwards filtered through bags of flannel or canvas to separate the particles of carbon. But as a portion of the charcoal passes through the filters, the sugar-solution is afterwards boiled

with white of egg, or blood which contains albumin. By the coagulation of the albumin all the impurities remaining suspended in the solution are removed, and the liquid then appears perfectly clear, and is finally evaporated in the boiling-pan to the point of crystallization, when it is run into earthenware moulds of a conical shape, which have an opening at the narrow extremity. The sugar soon hardens into small granular crystals, whilst the non-crystallizable portion formed during the ebullition drains into a vessel placed beneath to receive it, and forms the dark-brown, sticky substance, which is known as *treacle*, and used for a great variety of purposes. But as a portion of this colouring syrup always remains in the sugar, the loaves are washed by allowing water to percolate through them very slowly. When this is accomplished, the moulds are taken off, the sugar dried, and afterwards brought into commerce as *white* or *refined sugar*. If the sugar-solution is less evaporated, and placed in a warm room, it forms large yellow or brown crystals, and in this form it is termed *sugar-candy*.

The principal point in the manufacture of sugar is to produce the least possible quantity of molasses, the value of which is very trifling. To accomplish this, the evaporation is conducted with the greatest celerity, with exclusion of atmospheric air, and at a lower temperature, by removing the steam, as it is formed in the closed pan, by means of an air-pump. Hence a refinery requires, besides a considerable working capital, a great stock of expensive apparatus.

The separation of sugar from beet-root is conducted in precisely the same way; but the purification is more difficult, and requires greater care, since the beet-juice contains far more impurities than the juice of the cane, and, moreover, contains a less percentage of sugar. This circumstance, combined with the high price of fuel, the greater value of other field produce, and the improvement of the sugar process in hot climates, have led to a diminution of the cultivation of beet-root for the sake of its sugar on the continent of Europe.

The properties and uses of sugar are sufficiently well known; it may, however, be remarked, that sugar is a substance which undergoes no decomposition by itself, but, on the other hand, is even capable of preventing decomposition in other substances; and hence it is frequently employed for preserving fruit, &c.

4. GRAPE-SUGAR.

Formula = $C_{12}\,H_{14}\,O_{14}$.

134. This term is applied to the sugar contained in grapes, in fruit, and in honey, as well as that which is obtained by the decomposition of starch (§ 131). It has a less sweet taste than cane-sugar, and were it possible to convert it into the latter, to which it is so closely allied in regard to its composition, it would, indeed, be a discovery of incalculable value, since Europe would then be able to manufacture from the starch of the potato all the sugar required.

Milk-sugar ($C_{12}H_{12}O_{12}$) is a peculiar crystallizable kind of sugar, contained principally in milk: it is distinguished from cane-sugar by being less soluble and of inferior sweetness.

All kinds of sugar, under certain circumstances, suffer *fermentation*, a peculiar decomposition, by which the very important product, spirit of wine, is formed.

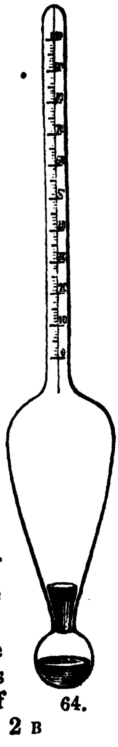
4. SPIRIT OF WINE.

Formula = $C_4 H_6 O_2$.

135. Spirit of wine or alcohol never occurs ready formed in Nature; but it is under all circumstances a product of the decomposition of sugar by fermentation, a process we shall more minutely describe farther on. When the spirit is formed in the fermented liquids, its separation is effected by distillation in a suitable apparatus (Phys., § 129). The spirit of wine, being more volatile than water, distils over first, and by repeated distillation over burnt lime it is entirely deprived of water, and in that form is termed *anhydrous* or *absolute alcohol.*

Spirit of wine is a colourless liquid, of an agreeably-refreshing odour and burning taste. Its specific gravity is 0·79, and its boiling-point 78° C. (172·4° F.). Many substances, as, for instance, salts which are soluble in water are not dissolved by spirit of wine; but, on the other hand, it dissolves most of the resins and ethereal oils, which are insoluble in water. Spirit of wine burns with a feebly-luminous flame, without smoke, and is, therefore, frequently used as a fuel, particularly on the Continent. For water it exercises a very powerful affinity, absorbing it even from the atmosphere. Moist vegetable or animal matters, when placed in spirit of wine, are deprived of all their moisture, being thus, as it were, dried and protected from decay. The burning sensation produced by spirit of wine upon the mouth and stomach is due to the separation of water from the mucous membranes of these organs. It produces also upon the nervous system a remarkable effect, which is known as intoxication.

Spirit of wine is miscible with water in all proportions. A mixture, containing from 80 to 85 per cent of alcohol, is commonly termed *spirit; brandy* contains only from 40 to 50 per cent. In commerce it is of the greatest importance to possess a ready method of determining the strength of such mixtures, *i. e.*, the quantity of alcohol contained in them. For this purpose is employed an instrument, called a *hydrometer* (Phys., § 88). Since spirit of wine has a less specific gravity than pure water, it follows that this instrument will sink lower in absolute alcohol than when it is placed in water. The hydrometer, which consists of a glass bulb-tube (fig. 64), is plunged into water, and the point cutting the surface is marked 0°. It is then placed in absolute alcohol, and the point to which it sinks is marked 100°. A series of mixtures are made, containing from 1 to 99 per cent of alcohol. The more alcohol the liquids contain, the deeper of course will the hydrometer sink. It is now successively introduced into each of these mixtures, and the point to which it sinks marked upon the tube. In this manner we obtain a scale, which accurately indicates the percentage of alcohol that may be contained in any spirituous mixtures, the strength of which we wish to ascertain.



64.

The instrument thus marked is termed the percentage volume hydrometer, and was invented by Gay-Lussac and Tralles: it is now chiefly used on the Continent for determining the quantity of

absolute alcohol in spirts. Unfortunately this convenient division has not always been adopted; Cartier, Baumé, Beck, Sikes, and several others, have divided the scale into an arbitrary number of degrees. A detailed description of these instruments and of their construction would occupy too much space; we shall, therefore, merely give a comparative table of some of the hydrometers now in use.

Specific Gravity.	Percentage Volume (Tralles).	Percentage Weight, at 60° F.	Degree, according to Cartier.	Degree, according to Beck.	Degree, according to Baumé.
1·000	0	0	10	0	10
0·991	5	4·0	..	..	..
0·985	10	8·0	12	..	..
0·980	15	12·1	..	3	13
0·975	20	16·2	..	..	..
0·970	25	20·4	14	5	..
0·964	30	24·6	15	6	15
0·958	35	28·9	..	..	16
0·951	40	33·4	..	9	17
0·942	45	37·9	18	..	..
0·933	50	42·5	..	12	20
0·923	55	47·2	21	14	..
0·912	60	52·2	..	16	24
0·901	65	57·2	24	19	..
0·889	70	62·5	27	..	28
0·876	75	67·9	..	24	..
0·863	80	73·5	30	27	32
0·848	85	79·5	35	30	35
0·833	90	85·7	..	34	38
0·815	95	92·4	40	38	42
0·793	100	100·0	44	44	48

When very dilute alcohol, or any liquid containing spirit, is exposed for some time at a temperature of 45° C. (113° F.) to the influence of the air, it absorbs oxygen, and becomes converted into acetic acid.

Spirit of wine, moreover, forms a very extensive series of products of decomposition, which, however, are of little value in the arts. The most important of these compounds is *chloroform*, which is a transparent liquid, of a specific gravity = 1·48; so that when dropped into water it sinks to the bottom. It is prepared by distilling dilute alcohol with chloride of lime (§ 82). The compound thus obtained has an agreeable odour, resembling that of ripe apples, and boils at so low a temperature as 60° C. (140° F.). If 20 or 30 drops of chloroform are placed in a handkerchief that is held before the mouth and nose, and the vapours thus inhaled, it produces in most persons a state of perfect unconsciousness and insensibility to pain; and hence it is now extensively employed for inducing this state during surgical operations. The composition of chloroform is expressed by the formula C_2HCl_3.

If 11 parts of alcohol of 85 per cent be gently heated with a solution of 1 part of mercury dissolved in 12 parts of nitric acid, a lively decomposition, and after a short time a deposition of white crystals, takes place. This new compound is termed *fulminating mercury*, because when struck or rubbed it is decomposed with a violent knell, and it is therefore used as one of the

ingredients in the manufacture of percussion caps. The fulminating mercury is a compound of *fulminic acid* ($C_4N_2O_2$), with two equivalents of protoxide of mercury.

5. ETHER.

Formula = $C_4 H_5 O$.

136. Ether, which is also commonly termed sulphuric ether, is a product of the decomposition of spirit of wine. When alcohol, the formula of which is represented by $C_4H_6O_2$, is mixed with sulphuric acid and distilled, it loses one equivalent of HO, and we obtain the compound C_4H_5O, or ether. This compound is a transparent, highly-volatile liquid, which boils at 35° C. (95° F.), and possesses an extremely penetrating odour. The specific gravity of ether is 0·713; it does not mix with water, nor dissolve any of the salts, but on the other hand, it takes into solution nearly all the resins, ethereal oils, and fats. The inhalation of the vapour of ether produces the same state of insensibility as chloroform.

6. FATS.

137. The fats occur ready formed in organic bodies, and we are still incapable of producing them by any artificial means. They are either solid or liquid, and in their chemical deportment display a remarkable similarity, whether they be obtained from plants or animals. Every kind of fat consists of an acid constituent, the *fatty acid*, in combination with an indifferent body termed *glycerine*.

The fatty acid, if liquid, is termed *oleic acid*, and, if solid and crystalline, *stearic acid*. The greater number of fats are mixtures of the compounds of these two acids with glycerine; and the solidity or fluidity of these bodies depends entirely on the preponderance of either the one or the other of these constituents. If it be stearic acid, then the fat is solid; but if oleic acid prevail, the fat is liquid.

For man the fats are of the greatest importance, since they form in his food the chief constituents for the development of animal heat; and hence it follows that an enormous quantity of fat is required as food by the inhabitants of northern climes. The fats are divided into the following groups, according to the purposes to which they are applied:—

As *food*, are used olive-oil, poppy-oil, nut-oil, butter, lard, suet, and several others.

As *fuel:* rape-oil, hemp-seed oil, palm-oil, cocoa-nut oil, train-oil (fat of marine mammiferous animals), tallow, &c.

For *soap:* olive-oil, rape-oil, hemp-seed oil, palm-oil, cocoa-nut oil, train-oil, and tallow.

For *plasters:* olive-oil and lard.

For *varnishes* and *oil-colours:* linseed-oil and nut-oil.

The fats are distinguished by their insolubility in water, spirit of wine, and in acids: they are, however, soluble in ether and caustic alkalies, and are perfectly non-volatile. Under the influence of heat, and of many chemical agents, the various fats give rise to the formation of peculiar volatile fatty acids, which have a strong and highly disagreeable rancid odour. The peculiar odour of the different kinds of fat always depends upon the presence of particular volatile acids, of which *butyric acid* is most common.

The greater number of oils and fats is unchanged by exposure to the air, and remains unctuous for years; some, however, solidify, by the absorption of oxygen, to a resinous varnish, and are, therefore, termed *drying oils*. The most important of these is linseed-oil. Oils expressed from seeds invariably contain certain quantities of water and vegetable mucilage, which are highly prejudicial to the use of these oils in burning. By long standing, or by agitation with a portion of sulphuric acid, and afterwards allowing it to stand till it becomes clear, a refined oil is obtained, which is perfectly free from those impurities.

Soaps.

138. The soaps are compounds of fatty acids, with potassa or soda. In commerce we distinguish two kinds, viz., *soft soaps*, consisting of oleic acid and potassa, and *hard soaps*, which contain stearic acid in combination with soda. Their preparation is essentially the same. As the affinity of the fatty acids is not sufficiently powerful to remove the carbonic acid from the soda, the soap-boiler first prepares a caustic *ley* (§ 66), by pouring water over a mixture of burnt lime and carbonate of soda (§ 73). By continued boiling of the ley with the tallow, the process of saponification is accomplished, a gelatinous mass being produced, containing a quantity of water, from which it has to be freed. For this purpose common salt is added, to form, with the water, a concentrated solution, which sinks to the bottom. On this saline stratum swims the soap, which, on cooling, becomes solid. The solidity and hardness of the soap depend upon the completeness of the saponification, and on the separation of the soap from the lees. When these conditions have been perfectly fulfilled, the product is called *perfect* soap. From 10 to 50 per cent of water or weak ley may be added, and stirred into the soap during cooling, and in this way the yellow or ordinary soap is produced, which, of course, is deteriorated in value exactly in proportion to the amount of water in its composition. This renders the real value of soap so difficult to be ascertained, and leads to many frauds in its manufacture and sale. Mottled and other coloured soaps are prepared by mixing colours with it during its preparation; but this is unattended with the least practical advantage.

Lead plasters are compounds of oleic acid with protoxide of lead, which are obtained by heating oil with either litharge or minium. By employing a low temperature the white-lead plaster is formed; but at a stronger heat is produced the brown variety, which is known under the name of *brown diachylon.*

The compound of stearic acid with *lime* is solid and insoluble in water. If, therefore, a soda-soap be placed in a calcareous water (§ 80), an insoluble lime-soap is produced, which coagulates in white flakes. Waters of this kind are consequently unsuited for the purposes of washing; they may, however, be rendered fit for use by mixing with them a little milk of lime, drawing off the clear liquid, and adding to it a solution of soda till no farther turbidity is produced.

Stearin Candles.

139. These candles are made of pure stearic acid. For this purpose a lime-soap is first prepared by saponifying tallow with milk of lime. The stearate of lime thus produced is decomposed by sulphuric acid, which combines with

the lime to produce sulphate of lime; and sets the stearic acid free. The acid is then freed by pressure from any adhering oleic acid; it then presents the appearance of a beautifully-white crystalline mass, which has lost its greasy character, and, after the addition of a portion of wax, is ready for forming candles. Stearic acid reddens blue vegetable colours, and hence the spots from stearin candles frequently attack the colour of cloths. The composition of this acid is $= C_{68}H_{68}O_5$.

7. WAX.

140. This substance is allied in its general properties to the fats. It is met with as a product of the vegetable kingdom in the pollen of flowers, and many other parts of plants; it is, however, frequently coloured green, brown, or red by being associated with resin or colouring matters. Bees also have the power of producing wax from the honey by the digestive process; and this wax so produced, together with what they collect from the farina of flowers, they use in the construction of their cells. By melting the honeycomb we obtain the crude wax, of a yellow colour and peculiar odour, both of which are partly due to the presence of honey. Thin plates of this impure wax, when moistened and exposed to the influence of solar light, become perfectly bleached. When thus purified it is colourless, odourless, and tasteless, insoluble in water, difficultly soluble in boiling alcohol, but pretty soluble in hot ether.

The specific gravity of wax is 0·96, and its fusing-point 68° C. (154·4° F.). Like the fats, it chiefly consists of a substance saponifiable by potassa-ley, namely *cerin*, and another body called *myricin*. Wax is used in medicine, in the manufacture of candles, and for many other purposes. Tree-wax, which is sometimes termed Chinese or Japanese wax, is obtained by exhausting with boiling water the bark and fruit of several trees; it agrees in all its essential properties with bees'-wax.

8. VOLATILE OILS.

141. The volatile or *ethereal* oils occur in the vegetable kingdom, and are in general the cause of the peculiar odours of different parts of plants, particularly of the flowers, leaves, and fruits, in which they commonly exist in droplets enclosed in the cellular tissue. These oils are all volatile, and, when pure, generally colourless. They possess a penetrating and, with few exceptions, an agreeable odour and burning taste. On paper they cause a temporary greasy stain, which, however, disappears as the oil becomes volatilized. They are almost entirely insoluble in water, but, on the other hand, they readily dissolve in spirit of wine, ether, and fats. With regard to their chemical composition, it may be remarked that they form two principal groups, of which the first consists only of carbon and hydrogen, whilst the members of the second group contain, in addition to these two elements, oxygen, and a few of them sulphur or nitrogen.

The volatile oils absorb oxygen from the atmosphere, whereby they solidify, and are finally converted into resinous bodies. When exposed to a low temperature, many of these oils deposit a solid crystalline substance, which has received the name of *stearoptène*. The application of the volatile oils is manifold. The substances in which they are contained are frequently employed as aromatics, and in the preparation of spirituous drinks, liqueurs, &c. They are,

moreover, frequently used in the preparation of medicinal waters, and as active remedial agents; for the latter purpose the oils themselves are in like manner employed.

The volatile oils are generally prepared by distilling a large quantity of the odorous herb with a comparatively small portion of water. The oil is thus volatilized, and is found floating upon the surface of the distillate.

142. The following oils are particularly worthy of being mentioned:—

Turpentine-oil ($C_{10}H_8$) is found in all the various species of fir. This oil is particularly important, from its power of dissolving many resins, and forming with them rapidly-drying *varnishes*. Turpentine is likewise extensively employed for dissolving and thinning oil-colours which are used in painting. Like most other volatile oils, it is highly inflammable, and burns with a strong smoky flame.

As constituents of perfumery, the following are principally used;—*Lemon-oil*, obtained from the rind of the lemon; *bergamot-oil*, from the rind of the bergamot-citron; *orange-flower oil; clove-oil*, from cloves; *cinnamon-oil; lavender-oil; bitter-almond-oil* and *rose-oil* (otto of roses), the latter being prepared chiefly in the East, and is exceedingly costly.

Juniper-oil, aniseed-oil, fennel-oil, cumin-oil, cinnamon-oil, clove-oil, and *peppermint-oil* are chiefly employed for flavouring spirits and liqueurs.

The *oil of chamomile*, which is distinguished by its beautiful blue colour, is employed as a remedial agent.

From the volatile oil of a tree (*Laurus camphora*) growing in the East Indies, a solid white substance separates, which is known under the name of *camphor*. This substance is employed as a perfume; and likewise in medicine, both as an internal and external stimulant.

The peculiar odour of spirit prepared from corn and from potatoes is due to the presence of a volatile oil, called *fusel-oil*, or hydrated oxide of amyl ($C_{10}H_{11}O,HO$).

Bitter almonds yield a volatile oil, which possesses the peculiar odour of hydrocyanic acid, and is extremely poisonous. A pungent oil containing sulphur is found in mustard and in onions. The chemical characters of these oils will be more minutely described hereafter.

9. RESINS.

143. The resins are products of the vegetable kingdom, and are observed to exude from many plants when they are cut or wounded. In general they are mixed with a volatile oil, which stands in intimate chemical relation to the resins. The resins have generally a yellow colour, and are devoid of crystalline structure. The oil, in admixture, imparts to them peculiar odours and tastes, and when burned, many of them emit agreeably-smelling products of combustion, and hence are frequently employed for fumigations. The resins are insoluble in water; but, on the other hand, they readily dissolve in alcohol, ether, and the volatile oils. If these solutions of resin be thinly spread upon wood or any other substance, and exposed to the air, the solvent is slowly volatilized, and there remains a brilliant coating of the resin, which is called *varnish* or *polish*. It has already been mentioned that the resins are non-conductors of electricity. With regard to the chemical characters of resins, we may remark that they deport themselves as weak acids, and form with strong

bases a series of compounds similar to those of the fatty acids; such bodies are the resin-soaps, some of which are employed in the arts. These resinous acids are readily separated from their combinations by stronger acids, and are thus obtained in a colourless, odourless, and crystalline form. The following are the most important resins:—

144. *Turpentine*, which exudes from the various pine or fir trees, particularly from the larch, is a mixture of volatile oil and resin. By distillation with water the turpentine-oil is volatilized, while a brown resin remains, which is known under the name of *colophony*. When the turpentine is dried in the air, we obtain the *yellow-pine resin*. By agitating the fused colophony with a portion of water, the two combine to produce the brown opaque *pitch*. The numerous applications of these resins is well known.

Copal is imported from the East Indies in bright-yellow pieces. When fused and dissolved in hot linseed-oil it forms the well-known copal-varnish, which is the most durable of all the varnishes, since it is not affected by spirit of wine.

Mastic and *sandarach* are resins consisting of white or bright-yellow tears, which form transparent varnishes when dissolved in spirit of wine. They are chiefly employed, with benzoin and storax, in fumigations.

Shellac exudes from the punctures made by an insect allied to the cochineal in the barks of several trees growing in the East Indies. It is much employed in the manufacture of sealing-wax, and when dissolved in spirit of wine it forms the common polish (French polish) of the cabinet-maker. It may be perfectly decolorized by chlorine, and afterwards employed as a colourless varnish.

Jalap-resin, which is obtained from the jalap-root, is much used in medicine as a powerful purgative.

Caoutchouc or *Indian-rubber* is contained in the milky juice of many plants, as, for instance, that of the lettuce. It is, however, prepared only from the juice of some trees, growing in South America and the islands of the Indian Archipelago. The extreme elasticity of this interesting substance has led to its employment in the manufacture of water-proof cloth, which was first introduced by Macintosh of Glasgow. For this purpose the caoutchouc is dissolved in coal-tar naphtha (§ 170), which is obtained as a secondary product in gas-works.

Gutta-percha has been imported into Europe, from the East Indies, only since 1843. It is obtained from a large tree, growing in Singapore, Borneo, and other islands, partly by collecting the milky juice, and partly by removing the layers of inspissated sap from the bark of the tree. It occurs in commerce in two forms—in small pieces, resembling the shavings of leather, and in blocks of a whitish-gray colour, which have the appearance of decayed wood. Gutta-percha is insoluble in water, spirit of wine, soda and potassa-ley, and in weak acids; but is partly soluble in ether, and readily soluble in turpentine-oil. Its most important property is that of becoming, in boiling water, soft and as plastic as wax, so that we may form with it objects of every possible shape, and take impressions of works of art, since it perfectly retains, after cooling, the form which is given to it. Gutta-percha is extremely tough, but is not elastic. This latter property, however, may be readily imparted to it by the addition of a portion of caoutchouc.

Amber is a resin occurring in the mineral kingdom. Its origin appears to

stand in intimate connection with the submerged forests which now yield the brown-coal of the Continent. This beautiful yellow and hard resin is worked into many objects of art; and when fused by heat, and dissolved in hot turpentine-oil, it forms a very durable and frequently-used varnish, which is not affected either by soap or spirit of wine.

10. GUM RESINS.

145. These substances are mixtures of resins, gums, volatile oils, and occasionally other substances. They exude from various plants in tropical climates, and are of high importance principally by reason of their medicinal qualities. The most important are:—*Gamboge*, which is employed as a beautiful yellow paint; *ammoniacum; assafœtida*, termed devil's dung (*Stercus diaboli*), on account of its remarkably disagreeable odour; *myrrh; aloes*, a bitter and drastic purgative; *opium*, and many others.

11. COLOURING MATTERS.

146. From the endless variety of colours displayed by the vegetable kingdom, we derive comparatively few colouring matters, since the greater part, particularly those of flowers, are rapidly destroyed by light and air. The more durable colouring matters manifest so variable a deportment, that it is impossible to depict them in general, and to describe them in detail would occupy too large a share of an elementary work. Some of these colouring matters are soluble in water, spirit of wine, or ether; they partly combine, like acids, with bases, and particularly with alumina (§ 86); they are all destroyed by chlorine. A few combine immediately with wool, silk, and cotton; others only when these materials are previously *mordantized, i. e.*, impregnated with alum, or some other body which has the power of fixing the colour upon them. Since most of the colouring matters are devoid of crystalline structure, their chemical characters are less known than those of the above-described indifferent organic substances. The most important colouring matters used in dyeing are the following:—

Yellows: Woad (Isatis tinctoria); *fustic; yellow oak; yellow berries*, or Persian berries; *turmeric*, or yellow root; and *annatto.*

Reds: Dyers' red, or *madder*, a root which is indisputably one of the most important materials employed in dyeing, and yields very durable red, violet, and brown colours; blue or *Campeachy wood;* red or *Brazil wood; saffron-wood; cochineal*, an insect living in South America upon various kinds of cactus, and from which the beautiful purple-coloured carmine is prepared; *archill* and *cudbear*, prepared from lichens; and, lastly, *dragons' blood.*

Greens: Only few of these are known; however, the sap of the buckthorn is employed under the name of *sap-green.* The green leaves of plants owe their colour to the so-called leaf-green or *chlorophyl*, which is of a resinous nature, but is unsuited to the purposes of dyeing.

Blues: To these belong *litmus*, which is obtained from certain lichens. It is employed by the chemist in the preparation of test-papers, which are used for ascertaining the acid or alkaline nature of bodies (§ 17).

The most important of all the blue colours is *indigo*, which is a nitrogenous body, and is prepared from several plants growing in the East Indies. Its

chief superiority consists in the extreme durability of its colour, since it is not reddened even by the strongest acids.

12. VEGETABLE MUCILAGE.

147. Mucilage is contained in many vegetable substances, to which it imparts the property of forming with water an adhesive slimy liquid, which is employed for many purposes, especially as a palliative in hooping-cough and diseases of the chest. Substances which consist almost entirely of dry mucilage, or contain a very large quantity, are—*tragacanth-gum*, *cherry-gum*, *salep-root*, *carrageen-moss*, *linseed*, *quince-seeds*, *marsh-mallow roots*, and many others.

13. VEGETABLE GELATIN.

148. This substance, which is termed also *pectin*, and is closely allied to the foregoing, is contained in the juice of most fruits and roots. If such a juice, as, for instance, that of the raspberry, be boiled with sugar or mixed with spirit of wine, the gelatin will be found to deposit in the form of a transparent mass.

14. VEGETABLE FIBRE.

149. The principal mass of plants consists of woody fibre, which is formed partly of small hollow tubes and partly of cells. Within these tissues are enclosed various other substances with which we have already become acquainted, namely, starch, chlorophyl, sugar, colouring matter, &c., which, however, may be completely separated by washing with water, spirit of wine, acids, and other solvents. The composition of the woody fibre thus purified may be expressed by the formula $C_{12}H_{10}O_{10}$, or, in other words, 100 parts contain 44·4 carbon, 6·2 hydrogen, and 49·4 oxygen.

Bleached cotton, flax, hemp, and paper prepared from linen, are tolerably pure woody fibre, which is neither soluble in water nor in any other liquid without decomposition. On the other hand, when immersed in liquids, it has the power of imbibing them, a property on which depends the nutrition of plants. When woody fibre, saw-dust, or straw, is treated with dilute sulphuric acid, it is first converted into a kind of gum, and finally, by long ebullition, into grape-sugar. If heated with concentrated solution of potassa, the elements of the fibre become grouped into oxalic, acetic, and carbonic acids, which unite with the potassa and produce salts.

When cotton-wool is submitted to the influence of fuming nitric acid, it suffers a remarkable change, and afterwards, when properly dried, possesses the property of exploding with great violence either by the blow of a hammer, or when heated to a temperature of from 60° C. to 90° C. (140° to 194° F.). This new compound, which is known under the name of *gun-cotton*, is now used for fire-arms, and more frequently for blasting in mines. The mode of preparing it is to immerse cotton-wool for a space of four or five minutes in a mixture of 1 part by weight of fuming nitric acid with 1½ to 2 parts of sulphuric acid, and subsequently washing it in pure water and drying it at a temperature of 50° C. (122° F.)

With many basic salts, particularly those of alumina and sesquioxide of iron, as well as with colouring matters, vegetable fibre has the property of combining in such a manner, that these substances form upon it a more or less

durable adhesive coating. On this property is based the process of dyeing linen and cotton cloth (comp. § 86).

Wood, the principal mass of which consists of vegetable fibre, is not only of the highest importance as a building material, but is of essential value as a fuel. In the latter respect we shall submit it to a closer examination when we speak of the decomposition of organic bodies. On that occasion, too, we shall describe the carbonaceous products, such as humus, peat, turf, brown-coal, and coal, which are produced, under different influences, from the decomposition of vegetable fibre.

b. Nitrogenous Indifferent Substances.

150. Under the non-nitrogenous organic compounds, such as starch, woody fibre, gum, and the various kinds of sugar, we have become acquainted with a series of bodies, which show by their composition and certain phenomena of decomposition that they mutually stand in intimate relation. The fats likewise offer to us a group of similarly-composed bodies, which when mixed together in various proportions, constitute the different fatty substances of the vegetable and animal kingdoms. The fact that all these bodies consist only of three primary elements, viz., carbon, hydrogen, and oxygen, and that moreover by their chemical deportment they may be readily prepared in the pure state, has rendered it possible for us to perfectly elucidate their composition and the metamorphoses they suffer under certain influences.

In a similar manner, we find now in vegetable and animal substances another group of bodies, which exhibit a remarkable concordance in their chemical constituents and properties. These bodies, which are generally termed *albuminous* compounds, are—white of egg or *albumin*, *fibrin*, and *casein*, the substance of cheese. These three bodies contain, in addition to carbon, hydrogen, nitrogen, and oxygen, a portion of sulphur and phosphorus. Our knowledge of the composition of these substances, however, is at present very imperfect, partly because we cannot readily prepare them in a state of purity, and partly from the extreme difficulty of determining accurately the proportions of nitrogen, sulphur, and phosphorus, which occur only in comparatively small quantities. But we know that the proportionate weights of the constituents of albumin, casein, and fibrin are very nearly the same, and hence they have hitherto been regarded as identical. Recent investigations have, however, not confirmed this supposition. We shall here confine ourselves to the description of their well-known general properties, and give the composition which has been assigned to them by the most recent investigations.

100 parts by weight of these bodies contain on the average 53 carbon, 7 hydrogen, 22 oxygen, and 16 nitrogen. The proportion of sulphur and phosphorus, however, varies in these different substances from $\frac{1}{2}$ to 2 per cent. The greatest quantity of the former element is found in the albumin of the egg, in which it amounts to from 1·7 to 2 per cent.

151. The general properties of albuminous bodies are the following: they are not crystallizable, but appear in the moist state as a white mass, which presents, when dry, a semi-transparent horn-like appearance. In the systems of plants and animals they are held in solution by water, and hence occur in the liquid state. But under the influence of vitality, of heat, or by mixing their solutions with a weak acid or spirit of wine, they become converted into

an insoluble modification. In the latter form, they are insoluble in water, spirit of wine, ether, and fats. They dissolve, however, in weak solutions of the caustic alkalies, and are again partly precipitated unchanged by acids. The albuminous bodies dissolve in concentrated hydrochloric acid, with a beautiful dark-blue colour; they are likewise slowly dissolved by the acid liquid of the gastric juice. If the albuminous bodies are left in the moist state to spontaneous decomposition, *i. e.*, to putrefaction, they evolve an extremely offensive odour, which is due to the elimination of carbonate of ammonia, sulphide of ammonium, and butyric acid. It is worthy of remark, that these bodies, when undergoing spontaneous decomposition, have the property of causing a peculiar decomposition of sugar into carbonic acid and spirit of wine, whenever they are brought into contact with its solution.

The albuminous bodies are of the highest importance as constituents of food, since the solid parts of flesh, blood, brains, and many other animal substances, consist chiefly of these compounds. Hence we consider those alimentary substances which are rich in albumin, fibrin, and casein as the most nutritious, and suited to the formation of flesh, blood, &c.

1. ALBUMIN.

152. Albumin is a constituent of all those vegetable and animal juices which coagulate when heated. If any green vegetable matter, such as the leaves of cabbage, &c., be crushed and pressed, we obtain a green liquid, from which the albumin separates on application of heat. The albumin thus prepared has a greenish colour, due to the presence of chlorophyl (§ 146), which may, however, be readily separated by means of spirit of wine. When beetroot and potatoes are sliced and digested for some time in water, the albumin these substances contain will enter into solution, and, on heating the water, will be found to separate in white flocks. Albumin, in the purest form, is contained in the egg, and likewise in blood. When fresh blood is allowed to stand some time it is observed to separate into two parts, namely, into a solid called the *coagulum*, and a fluid termed *serum* on which the former swims. The latter contains in solution the albumin, which coagulates when the serum is heated.

The essential properties of albumin are the following: it is contained in the juices of plants and animals in the *soluble* condition, which it loses when heated to the temperature of boiling water. It separates then in the form of a white flocculent mass, which is not again dissolved by water, and in that form is commonly termed *coagulated* albumin. By coagulation of the albumin it envelops other substances which may be contained in the liquids, and thus removes them; hence all albuminous juices are well adapted for clarifying turbid beer, wine, and other liquids, and are employed particularly in the fabrication of sugar (§ 133). When an albuminous liquid is mixed with spirit of wine or an acid, the albumin is at once precipitated.

2. FIBRIN.

153. *Fibrin*, like albumin, is known in the solid and fluid conditions. The red mass which constitutes the flesh or muscle of animals is solid fibrin. It is contained in a soluble state in blood, and separates on cooling of the latter into the so-called *coagulum*. In this form the fibrin is coloured by a red substance

contained in the blood, which, however, may be easily removed by washing. Vegetable fibrin (or *gluten*) is prepared by placing wheaten flour in a bag, and kneading it with fresh portions of water until the latter no longer becomes milky. The water removes the starch contained in the flour, and leaves a tenaceous gluey mass, which is known as *gluten*, and, when purified, deports itself in a similar manner to animal fibrin.

3. CASEIN.

154. Milk is a mixture of fat (butter) with a solution of *casein* in water. When the milk, freed as much as possible from butter, is heated, a white pellicle is formed upon the surface, and becomes renewed as often as it is taken off. This skin which forms upon the milk is casein. Casein also coagulates by heat, not suddenly like albumin, but only slowly; it may, however, be instantly coagulated, when to the heated liquid containing it, a few drops of acid are added. When beans, peas, or leguminous fruits generally, are bruised and macerated with water, the casein becomes dissolved; by heating the solution it is separated as a white pellicle, which exhibits the greatest similarity to the casein obtained from milk. If milk be allowed to stand for some time it becomes sour, from the conversion of the sugar it contains into lactic acid (§ 126), which then induces the coagulation of the casein. The most remarkable effect upon casein is produced by the so-called *rennet*, which is a certain part of the stomach of a young calf. If a small quantity of this rennet be introduced into milk, the casein is forthwith coagulated, but in what manner this change is induced we are as yet unable to offer a satisfactory explanation.

Casein, when mixed with the cream of the milk, constitutes the fat cheeses, whilst the poor or thin cheeses are prepared from skimmed milk. In the ripe or decayed cheeses the casein has partly passed into a state of putrefaction, and consequently is changed in its chemical characters.

4. DIASTASE.

155. When barley is moistened with water, it begins after some days to germinate. The germinated barley, when dried, is termed *malt*, and differs essentially from the barley which yields it. If we mix ground malt with water, and add to the filtered liquid a portion of spirit of wine, the *diastase* will be precipitated in admixture with albumin and gum. This substance is distinguished by the remarkable property of transforming starch into gum and sugar, in the same manner as we have seen, at § 131, this change can be effected by acids. Hence malt contains but little starch, the greater part being transformed by the diastase into gum and sugar, as is proved by the sweet taste which malt possesses. This property of diastase is turned to advantage in the preparation of saccharine fluids, which are employed for the manufacture of beer, brandy, and vinegar (see Fermentation, § 160).

Gelatin (Glue).

156. Various parts of the animal body, particularly the skin, cartilage, and the soft portions of the bones (comp. § 51), dissolve completely by long ebullition in water, and produce a liquid which solidifies on cooling to a jelly, which, after being dried, is termed *gelatin*. Hence those parts of the animal body are

also termed the *gelatinous* formations. The application of common gelatin or *glue* as a cement is well known.

The purest gelatin is prepared by dissolving isinglass in boiling water, whereby we obtain a colourless, odourless, and tasteless liquid. The gelatin, when dry, is unaltered by exposure to the air, but when boiled for some time with dilute sulphuric acid it is converted into an exceedingly sweet sugar, which is termed *gelatin-sugar*. A remarkable property of gelatin is the power it possesses of forming with tannic acid a compound which is insoluble in water. If a solution of this substance be mixed with a decoction of oak-bark or nut-galls, a large flocky precipitate is immediately produced.

Leather.

157. The animal skin can be transformed into such a peculiar condition, that whilst it withstands the putrefactive process, it at the same time affords, by its toughness and pliability, a highly-valuable material for different purposes. The skin of animals in this form is termed *leather*, of which three principal kinds are known in commerce, viz., Morocco, shamois, and Russian, besides several others.

Sole-leather, or shoe-leather, is nothing more than an insoluble compound of skin with tannic acid. In the preparation of this variety, the hides are first sprinkled with salt and piled upon each other in pits, where they spontaneously *heat*, or as it is technically called *sweat*, and admit then of the hair being easily removed. The hides are afterwards placed in running water until they are soft and porous, and then they are thrown into pits containing the tan liquor, which is prepared by extracting oak-bark with water. The more perfectly this liquid penetrates through the skin, the more completely will the latter be transformed into leather. Several months are commonly required to complete the process.

The hair and fat adhering to the skin may also be removed by treating the hides with caustic lime. After the process is completed, and the lime removed by the aid of a weak acid, the properties of leather are given to the hides by maceration in a solution of alum and salt, as in the preparation of *white leathers*; or they are converted into shamois leather by frequent immersion in oil and pressing them, the excess of oil being finally removed by a solution of a caustic alkali.

II. PECULIAR DECOMPOSITIONS OF ORGANIC COMPOUNDS.

158. From what has been advanced, we know that the body of a plant or that of an animal is an agglomeration of different substances, with which, both in reference to their properties as well as to their chemical composition, we are already acquainted. Thus the chief mass of the animal body consists of fibrin, gelatinous tissues, albumin, and fat, independently of phosphate of lime, which forms the solid constituent of bones. The substance of a plant is composed of ligneous fibre, chlorophyl, albumin, gum, starch, oil, &c.; and it is to be remarked, that most of these animal and vegetable substances are either held in solution by water or mollified and penetrated by it, as, for instance, the fibrin, which constitutes the muscle. Hence water is to be considered as a principal constituent of these bodies. We know, moreover, that carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus, are the elements that enter into

the composition of these substances, which represent highly-complicated compound groups.

Thus the bodies of plants and animals are organizations of wondrous complexity and diversity of *material* and *structure*; and so long as the breath of life, the animating principle, is present, so long is the body preserved from internal decay, and protected from the external effects of wind and weather. But as soon as the vital principle has quitted the corporeal structure, the constituent parts obey the law of chemical attraction. The highly-complex groups of the body can no longer exist as such; they separate or fall to pieces, and their molecules arrange themselves in simpler combinations, which appear as products of decomposition. Still the decay of the body is not merely occasioned by the highly-complex nature of its internal structure, but the influence of the surrounding oxygen and the water of the atmosphere likewise contribute essentially thereto, and give for the most part the primary and principal impulse to decomposition.

This process is still more rapidly and completely effected by the joint influence of a higher temperature. If the influence of external air be excluded, the process of decomposition receives the name of *dry distillation*, whilst the transition of organized bodies into simple combinations, by the action of air and water at the common temperature, is called *spontaneous decomposition.*

It is evident that all the products resulting from the decay of organic bodies must be of more simple composition than the bodies themselves, that they can contain only the same simple materials which we find in those organic bodies, and that the sum of their weight can only exceed the weight of the decomposed body, when, during the process of decomposition, oxygen and water have been absorbed from the atmosphere.

(1.) Spontaneous Decomposition.

159. The resolution of organic bodies into simple compounds, at the ordinary temperature, is called spontaneous decomposition. This process, however, under different circumstances has received different appellations. If the decomposed body contained sugar, and if alcohol be found among the products of decomposition, the process is called *fermentation.* If putrid odours are evolved during the decomposition, it is termed *putrefaction.* When an organic body is destroyed by the combined influence of atmospheric oxygen, light, and moisture, it is said to be *rotted* or *decayed.*

Fermentation.

160. In all the saccharine juices of plants, as, for instance, in the juice of the grape, of fruit, of the sugar-cane, of the beet-root, in an infusion of malt (§ 155), there is found, in addition to sugar, a nitrogenous substance, in general, albumin or vegetable fibrin. When such a liquid is exposed to the air, there first commences a change in the nitrogenous constituent, which absorbs oxygen, and slowly separates from the liquid in the form of a brownish precipitate, called *yeast* or *ferment.* It appears as if this change, going on at every point of the entire liquid mass, gives the first impulse to the decomposition of the sugar, for as soon as the process has commenced, the group of particles forming the sugar arrange themselves in two other groups, viz., into alcohol and carbonic acid. The latter, which at every point of the surface of the liquid rises in

small bubbles, occasions the frothing or rising of the liquid, whereby the fermentative process is so readily recognised.

The decomposition of sugar into alcohol and carbonic acid may be represented by the following formula:—

1 atom of anhydrous grape-sugar $= C_{12} H_{12} O_{12}$ decomposes into

$$\left.\begin{array}{l}\text{2 atoms of alcohol} = C_8 H_{12} O_4 \text{ and} \\ \text{4 atoms of carbonic acid} = C_4 O_8.\end{array}\right\} = C_{12} H_{12} O_{12}$$

The fermentation is completed when all the sugar is converted into alcohol; the liquid is then put into a still and the alcohol separated by distillation.

The yeast, separated as a deposit during the process of fermentation, possesses the property of exciting the decomposition of a new portion of saccharine liquid, with which it may be mixed, a very minute quantity of yeast being sufficient to cause the fermentation of a very large quantity of sugar. Finally, however, the yeast loses the power of exciting fermentation, by the completion of its own decomposition.

The fermentation of saccharine liquids, however, does not take place under all circumstances. The contact of atmospheric air, and a temperature of from 20° to 30° C. (68° to 86° F.) is necessary. Under 10° C. (50° F.) fermentation does not proceed. Certain substances when added to fermentable liquids, only in very minute quantities, have the power of preventing decomposition; such are, for instance, volatile oil of mustard, sulphurous acid, nitrous acid, and several others.

Yeast loses its power of exciting fermentation when perfectly dried or heated to a temperature of 100° C. (212° F.), or if mixed with alcohol, acids, or alkalies. Artificial yeast, or *leaven*, is prepared by exposing a piece of dough for some days to a moderate temperature, until it acquires a vinous odour.

Spirituous Drinks.

161. These liquids are all products of the fermentation of saccharine fluids, and are either prepared by subsequent distillation, as spirit of wine, and the various kinds of brandy; or without distillation, as wine and beer.

Distilled spirituous liquors, of course, contain only volatile constituents, their chief bulk being alcohol and water. In general, they are distinguished by different, and more or less agreeable flavours, according to the substance from which they are derived. The cause of this is, that during the fermentation of these substances a peculiar volatile oil or ether is formed, which possesses a characteristic odour, and imparts it to the spirit. Thus the spirit prepared from potatoes and corn owes its odour and flavour to the presence of fusel-oil (§ 142). *Rum* is prepared from cane-sugar, and *arrack* from fermented rice. On the table-lands of Asia the inhabitants prepare a highly-intoxicating beverage from milk-sugar.

Starch is converted into grape-sugar, both by means of sulphuric acid and also by diastase (§ 155), hence we in general avail ourselves of amylaceous vegetable matters for the preparation of spirit. Mashed grain, or boiled potatoes, are for this purpose mixed in the fermenting vat with the mash and afterwards distilled.

Various amounts of alcohol are contained in wine, according to the quantity of saccharine matter in the grapes. Whilst the ordinary wines of Germany

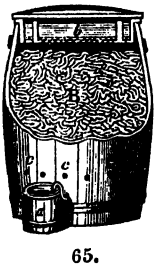
contain only about 8 to 10 per cent of alcohol, and the strongest Rhenish wine from 12 to 14 per cent, we find in the wines of the south of France, Spain, and Portugal, from 18 to 20 per cent. The wine, besides alcohol, contains those constituent parts of the grape-juice which are soluble in the spirit. In addition to colouring matters, wine, especially Rhenish wine, contains bitartrate of potassa (§ 120), which imparts to it an acid taste. We also find in many wines, especially those of the south of Europe, sugar, which occurs naturally in it, or sometimes is intentionally added to it. The bouquet of wine is due to the presence of peculiar ethereal liquids. Red wine contains, besides the colouring matter, a portion of tannic acid, which imparts to the wine an astringent flavour.

Beer is prepared by infusing germinated barley (malt) in hot water, and boiling the sweet-wort thus obtained with hops; it is afterwards placed in a wide exposed vessel called a cooler, where its temperature is reduced as quickly as possible. The cooled liquid is then conveyed to the open fermenting tun, in which it undergoes a slow process of fermentation until nearly all the sugar is converted into alcohol, when the beer is either drawn off for immediate use or barrelled for the cellar.

The constituents of beer are, besides water, from 4 to 5 per cent of alcohol, sugar, gum, which imparts to the beer its viscidity, the bitter principle of the hops, and carbonic acid, which is the cause of its frothing. Beer very readily becomes what is called sour or stale, that is, its alcohol is easily converted into acetic acid; and the weaker the beer the more readily is this change induced. This acidification is retarded by the bitter principle and volatile oil of the hops, and, consequently, strongly-hopped bitter beer can be preserved in a potable condition for a longer period than sweet beer. A low temperature, however, is essential to the preservation of the beer, and therefore it is generally placed in cellars where the temperature even in summer does not exceed 8°, or at most 10° C. (46° to 50° F.).

Acetic Fermentation.

162. Acetic fermentation depends upon the conversion of alcohol into acetic acid, by the influence of atmospheric oxygen. One equivalent of spirit of wine ($C_4H_6O_2$), combines with four equivalents of oxygen, and form one equivalent of acetic acid ($C_4H_4O_4$), and two equivalents of water (2HO). Acetic acid is manufactured by exposing alcoholic liquids, at a temperature of from 28° to 35° C. (80° to 95° F.) to the air. A great variety of substances are employed in the manufacture of acetic acid, such as the refuse obtained in making beer and wine. In general, however, a fermented mash (§ 161) is used and placed at suitable temperature in partially-closed vessels. The alcohol is thus slowly transformed into vinegar, the process being completed as soon as the liquid becomes clear.



65.

Alcohol may be very rapidly converted into acetic acid by allowing dilute spirit of wine to percolate several times through a vessel filled with shavings of wood (fig. 65). A very large surface of spirit being thus exposed to the influence of the oxygen of the atmosphere, the process is much facilitated.

PUTREFACTION.

163. This process yields products of a character very different from the foregoing. Here also it is necessary to bear in mind the elements of vegetable and animal bodies before we can pretend to form any precise idea of the products that result from their putrefaction. These are not the same under all circumstances, but vary essentially according as the putrefactive process takes place at a lower temperature and in the presence of water, or at a higher temperature with exclusion of moisture. Furthermore, animal substances yield, in consequence of the large proportion of sulphur and nitrogen which they contain, certain products in larger quantities than do vegetable substances, which are not so rich in these elements.

We may generally assume that, when the putrefactive process takes place at a lower temperature and in the presence of much water, *hydrogen* compounds are chiefly formed; whilst at a higher temperature and with less water, *oxygen* compounds are produced.

The following view may assist in rendering this mode of decomposition more intelligible:—

PRODUCTS of the DECOMPOSITION of VEGETABLE and ANIMAL MATTERS.

With much Water and at a lower Temperature.		With little Water and at a higher Temperature.	
Water - - - - - - - - - - -	HO	Water - - - - - - - - - - -	HO
Carbide of Hydrogen (Marsh-Gas) -	CH_2	Carbonic Acid - - - - - - -	CO_2
Sulphide of Hydrogen (Hydrosulphuric Acid) - - - - - - - - -	HS	Sulphuric Acid - - - - - - -	SO_3
Phosphide of Hydrogen (Phosphoretted Hydrogen) - - - - - - - -	PH_3	Phosphoric Acid - - - - - - -	PO_5
Ammonia - - - - - - - - - -	NH_3	Nitric Acid - - - - - - - - -	NO_5
x (O C S P N H).		x (H C S P N O).	

It is not, however, to be inferred that these products are so exclusively formed as is represented in the above table. On the contrary, the products of the one series are more or less produced among those of the other according to circumstances. Frequently at the commencement of the process, when there is still much water present, there appears more of the first series, and towards the termination there is more of the other, or the first pass subsequently even into the oxygen-compounds. The products which are formed likewise combine with each other, and produce more complex compounds, such as carbonate and nitrate of ammonia, sulphide of ammonium, and many others.

The medium surrounding the decomposing body itself has great influence or the nature of the products formed during spontaneous decomposition. If strong bases be present, particularly potassa or lime, acids are chiefly formed which unite with these bases. On this depends the formation of nitric acid, as already noticed (§ 33).

All the above-mentioned products of decomposition exist in manures, whether solid or liquid, and on their presence depends chiefly the nutritive

quality of these agents as food of plants. But as these combinations, without exception, are volatile, manures lose their efficiency by exposure to the atmosphere. Hence many attempts have been made, by the addition of substances such as lime, clay, gypsum, sulphate of iron, sulphuric acid, &c., to fix those volatile acids and bases, and to retain them in the manure.

164. Putrefaction is prevented by excluding the influence of water or of the air, or by a very low temperature. All thoroughly-dried animal and vegetable substances are not susceptible of putrefaction. Drying is accomplished either by exposure to the atmosphere, by artificial heat, or by the application of such substances as have the property of abstracting the water on account of the greater affinity they have to this fluid. Such substances, for example, are common salt and sugar; and on this principle depends the process of curing by means of these substances. Spirit of wine has the same effect on substances which are immersed in it. If meat, vegetables, and similar kinds of provisions be put into tin vessels which are filled with hot water, and on which is soldered a perfectly air-tight lid, and if then they are heated for some hours in boiling water, such provisions can be kept more than a year without their undergoing any change. This mode, discovered by Appert, is indeed adopted in preserving food for long sea-voyages or for winter store. The success of this process altogether depends on the complete exclusion of the oxygen of the atmosphere.

A mammoth, an animal which is now extinct, has been discovered in Siberia frozen in the ground. The hide, hair, and flesh, were found to be in a perfect state of preservation, so that the flesh was eaten by dogs. This animal must have remained at least several thousand years in this condition, and it affords a very remarkable and convincing proof that cold prevents the process of putrefaction.

Many substances which arrest fermentation prevent or delay also putrefaction, such as creosote, pyroligneous acid, and likewise arsenic and corrosive sublimate. The preparation of mummies depends on this principle, viz., that of drying the body as much as possible, and subsequently introducing a variety of antiputrescent substances.

Slow Carbonization.

165. When the remains of plants, for example, wood, stems, roots, moss, &c., under partial or complete exclusion of atmospheric air and water, are submitted to spontaneous decomposition, their oxygen and hydrogen are slowly eliminated from the mass in the form of carbonic acid, water, and carburetted hydrogen (marsh-gas), while the residue becomes continually richer in carbon. This change is easily recognised by the colours of the bodies, which are so much the darker the more completely the carbonization has been effected. The change produced may be also proved by chemical investigation. The products which remain are ligneous earth, mould, turf, peat, and the different varieties of coal. All these substances are distinguished by the extent to which decomposition has taken place. The most important member of the series is common coal.

In ordinary cultivated soils there is always present a large portion of partially-decomposed vegetable remains, termed *humus*, which frequently

communicates to the soil a darker colour than is possessed by the uncultivated subsoil.

In consequence of the gradual decomposition of vegetable substances, we find in certain localities different kinds of carbonaceous materials, accumulated in such large masses as to be available as fuel. In fact, the forests growing on the whole surface of the earth, would be insufficient for our daily consumption, if we could not have recourse to the treasures which for thousands of years have been accumulated in the bowels of the earth. The vast importance of combustible substances, renders a more detailed account of them expedient.

166. *Turf* is undoubtedly the most recent of the carbonaceous formations. It owes its origin principally to the turf-moss, as it is called, (*Sphagnum palustre*,) which frequently covers the whole surface of extensive moist moors. When the roots and under parts of the moss perish, there grows up a new covering of moss, which also decays in the following year, and thus the vegetable mould increases by successive annual depositions, which in the course of from eighty to one hundred years become a considerably deep accumulation. The carbonizing process is incessantly active; the under layers increase in blackness and become consolidated by the pressure of the superincumbent mass. Hence the best turf is the oldest: its black appearance and great density scarcely allow us to recognise it as a vegetable product. The more recent turf is, on the contrary, brown, of a looser texture, and evidently appears to be a formation of vegetable mould, half-decayed stems of mosses and of roots, and dead parts of all sorts of plants that generally grow in such places.

Under particular circumstances, the turf is more or less mixed with earthy matter. Sometimes the latter substance is found in scarcely appreciable quantities, while occasionally it amounts to from 30 to 40 per cent of the whole. In the latter case, the greater specific gravity of the turf is no certain proof of its good quality; therefore, in determining the value of the turf, we must take into consideration the amount of ash which it yields.

167. The formation of *brown-coal* (a species of coal which occurs in many parts of Germany) is ascribed to a period anterior to the history of the human race. More or less large masses of wood have been suddenly buried, or gradually concealed and changed in appearance, by the constant accumulation of earthy deposits. Brown-coal presents the remarkable transition-process between ordinary coal and mere wood, and this, of course, differs according to the circumstances under which the coal has been formed. In brown-coal are found stems with the woody annular rings quite apparent; also seeds, leaves, and bark. Some specimens of this formation, on the contrary, are earthy, or black and solid, affording no indications of a ligneous or vegetable origin. The brown-coal, the name of which is derived from its colour, has considerable density, acquired by the pressure of the mass of earth under which it has been formed. We can form an idea of this enormous pressure from the fact that trunks of trees originally cylindrical have been flattened and pressed into an elliptical shape. This kind of coal is an excellent fuel, though sometimes associated with sulphide of iron, which gives to it a disagreeable odour when burned.

168. The origin of our common coal must be ascribed to a still earlier period. This, as well as brown-coal, is undoubtedly of vegetable origin, being

formed from stems of trees and other ligneous matter. But these, in a long series of years, and by constant pressure, have been so much altered, that, for a long time, the vegetable origin of coal was doubted. This doubt, however, has been removed, on the one hand, by the fact that turf and brown-coal form a transition-series between the vegetable matter and common coal, and, on the other hand, by the circumstance that different remains of plants or vegetable fossils are everywhere associated with the coal. Even stems of well-known forms of vegetation have been discovered. The microscope also plainly reveals the cellular structure, even in the most solid coal.

The difficulty of accounting for such astonishing masses of coal, sometimes found in layers of 40 feet thick, is still unresolved. It is certain that the carbonization of such enormous masses of wood must have been a process of many thousands of years' duration.

Coal is compact, black, and shining. Its specific gravity is 1·3, and if compared with the density of wood and of charcoal (§ 49, and Physics, § 34,) it becomes evident that the same bulk of coal contains a far larger quantity of combustible matter. On this account it is an excellent fuel, but being denser, it is more difficult to kindle, and requires a greater supply of air to keep it in combustion than either wood or charcoal.

We are not, however, entitled to consider coal as pure carbon. It always contains oxygen, hydrogen, and a small quantity, viz., from 1 to 2 per cent, of *nitrogen.* Moreover we meet with certain mineral constituents, particularly *sulphur* in combination with iron. It is evident that the dense superincumbent mass of earthy matter on the carbonaceous strata has prevented their complete carbonization. The carbonization, however, can be accomplished by a process analogous to that used in the carbonizing of wood (§ 49). In this process the sulphur, which is so prejudicial to the use of coal, is in the mean time separated from it: the product obtained is called *coke.* As this material, with the exception of its mineral constituents, consists entirely of carbon, and possesses a great density, it forms the most valuable of all fuels when a high degree of heat is required in a small space. Hence it is almost exclusively employed in generating steam in locomotives. Coke has a gray shining, almost metallic, sometimes a slaggy, appearance, and is so dense that it sounds when struck with a hard body. Coal is found under a great variety of aspects, and of very unequal composition and quality, as the subjoined tabular view shows very conspicuously. It is evident that it is of less value the more mineral, and consequently incombustible, materials it contains. The different kinds of coal, when pulverized and heated, comport themselves in three ways. They either swell up and finally cake together, and are therefore distinguished as *caking-coal,* this kind is particularly adapted for forges and for gas-lighting: or the particles of pulverized coal sinter together, and this coal is therefore called *sinter-coal;* whilst the so-called *sand-coal* remains powdery. The latter is much less valuable than the other varieties. One of the best kinds of coal occurring in England is the *cannel-* or *candle-coal,* which burns with a beautifully clear flame, hence its name. This property and the applicability of coal for gas-lighting depend chiefly on the amount of *hydrogen* it contains.

169. Now that we have in the preceding sections become acquainted with wood, turf, brown-coal, and coal, we will subjoin some general considerations

in reference to the value of these various combustibles, as materials for fuel. All our modes of obtaining artificial heat depend on the combination of carbon and hydrogen with oxygen, which produces the phenomena of combustion.

Hence it may be stated as a rule that those bodies which contain in an equal weight the largest quantity of unoxidized carbon and hydrogen are the most valuable fuels. In 100 lbs. of green wood we have only 20 lbs. of carbon, while 100 lbs. of dry wood contain 40 lbs.

The heat which fuel yields is entirely dependent on the manner of its combustion, since equal weights of coal under similar circumstances, when perfectly consumed, yield an equal supply of heat. A perfect combustion, however, is such wherein no particle of carbon escapes without being converted into the highest oxygen compound, namely, carbonic acid.

An evident loss of heat is experienced in every furnace from which unconsumed gas and vapour, in the form of smoke, or inflammable gas (carbonic oxide, which burns with a blue flame), escapes into the atmosphere.

In the use of fuel the following points are of importance, viz., the quantity of carbon, hydrogen, water, and mineral substances which they contain; then the density; and finally, the most perfect combustion by a sufficient draught of air.

COMPARISON of VARIOUS FUELS.

Dried at 100° C. (212° F.)	Density.	100 parts, by weight, contain			
		Carbon.	Hydrogen.	Oxygen.	Mineral Constituents.
Charcoal - - - - - - -	0·187	99·07	..	..	0·03
Coke - - - - - - -	1·08	95	..	..	to 5
Caking-coal - - - - - -	1·28	87	5	5	1·3
Cannel-coal - - - - - -	1·31	67	5	8	2·5
Brown-coal (best quality) - -	1·37	66	4·8	18	2·7
Turf (best quality) - - - - -	..	58	5·9	31	4·6
Brown-coal (ligneous) - - -	1·27	51	5	30	1·29
Beech-wood - - - - - -	0·728	49	6	44	..
Ditto (dried in the air) - - -	..	40	..	..	..

The above table clearly shows that the proportion of oxygen decreases in the same ratio as we proceed towards older carbonaceous formations; whilst in wood we find 44 per cent of oxygen, the quantity in many kinds of coal decreases to about 5 per cent.

(2.) DRY DISTILLATION.

170. The materials which are submitted to this process for the sake of the products obtained, are coals, wood, and the flesh of animals. The process is conducted in large manufactories, where the materials to be decomposed are heated in iron vessels of various forms, and to which suitable arrangements are appended for condensing and collecting the volatile products.

The combinations formed during the distillation depend chiefly on the composition of the bodies submitted to this process.

The following table affords a view of the different nature of the products obtained:—

PRODUCTS obtained from the DRY DISTILLATION of—

COAL.		WOOD.		ANIMAL SUBSTANCES.	
Water - -	HO	Water - -	HO	Water - - -	HO
Ammonia - -	NH_3	Naphtha - -	$C_2H_4O_2$	Sulphide of Ammonium -	NH_4S
Volatile Tar Oil	CHO	Acetic Acid -	$C_4H_4O_4$	Cyanide of Ammonium -	NH_4Cy
Tar - - - -	CHO	Volatile Tar Oil	CHO	Carbonate of Ammonia -	NH_4O,CO_2
Naphthaline -	$C_{20}H_8$	Tar - - -	CHO	Volatile Tar Oil -	CHON
Carburetted Hydrogen	CH_2	Creosote - -	$C_{14}H_8O_2$	Tar - - - -	CHON
Olefiant Gas -	C_4H_4	Carburetted Hydrogen	CH_2	Carburetted Hydrogen -	CH_2
Sulphurous Acid	SO_2	Carbonic Acid -	CO_2	Phosphoretted Hydrogen -	PH_3
Carbonic Acid -	CO_2	Carbonic Oxide	CO	Carbonic Acid -	CO_2
Carbonic Oxide -	CO			Carbonic Oxide -	CO
As Residue:		As Residue:		As Residue:	
Coke - - -	C	Charcoal - -	C	Nitrogenous Carbon	NC
x	C,H,O,S,N	x	C,H,O	x	C,H,O,S,N,P

Here, as well as in the putrefactive process, the products of the one series appear among those of the other series, though always subordinate in quantity.

In general the hydrogenated products appear first, such as acetic acid, naphtha, volatile oils, and water containing ammonia, which, however, are soon partly decomposed, and thus give rise to simpler combinations, such as carburetted hydrogen, carbonic acid, and carbonic oxide. The tar which appears in each of these cases is a body of no definite chemical composition, but rather a mixture of many substances, particularly of volatile oils, and is coloured black by carbon. Several of the substances found in the tar, on account of their properties and practical utility, have become objects of manufacturing industry; thus, for instance, is obtained, from this substance, by distillation with water, the volatile tar-oil which is employed as an illuminating material and as a solvent of caoutchouc.

The tar and tar-oil obtainable from animal substances are, however, on account of their penetrating and offensive odour, scarcely fit to be applied to any useful practical purpose.

The employment of carburetted hydrogen as an illuminating material has already been noticed in § 56. *Naphthaline* is a constituent, especially of the coal-tar, crystallizing in nacreous plates. It possesses a peculiar and not unpleasant odour, characteristic of lamp-black, which always contains a portion of this substance. *Creosote* is an oily colourless liquid, which is obtained also from tar, and possesses in a high degree the odour of smoke. It has an extremely hot taste, and is in some degree a preventive of putrefaction and fermentation.

Ammonia and its important combinations obtainable from animal substances by the process of distillation have been already described in § 78. The impure distillate which contains the ammonia is employed in medicine under the name of *spirit of hartshorn*. *Pyroligneous acid* is used in the preparation of acetic acid and of acetates, particularly of acetate of lead. This kind of vinegar, on account of its creosotic flavour, is never employed in domestic economy. Like nearly all the products of dry distillation, it possesses the property of arresting or preventing putrefaction and fermentation. Naphtha, or hydrated oxide of methyl (C_2H_3O, HO), obtained in the dry distillation of wood, posseses properties analogous to those of ordinary alcohol. Its radical, termed methyl (C_2H_3), yields a class of compounds possessing peculiar interest, and presenting the most complete parallelism in properties and composition to those of ethyl. Naphtha is colourless and of not unpleasant odour, and is employed in this country as a fuel for lamps, being less expensive than our highly-taxed spirit of wine.

NATURAL PRODUCTS OF DISTILLATION.

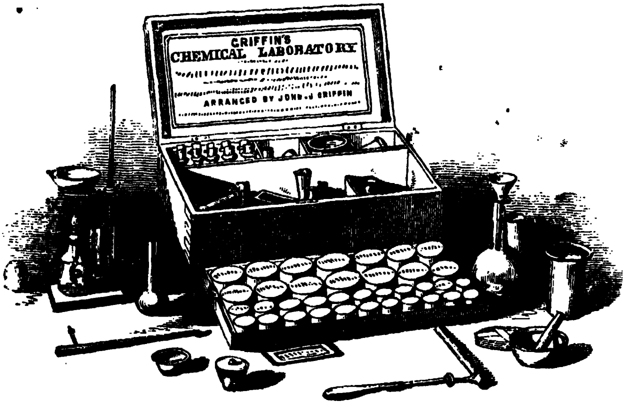
171. We are taught from the structure and origin of the crust of the earth that at different epochs the upper stratum has been ruptured by streams of glowing mineral substances proceeding from the interior of the earth. In places where this melted matter came in contact with those strata, the latter have been more or less altered in their qualities. If this action took place, for example, in the vicinity of coal, this material, through the influence of intense heat, might have been altered in the same manner, and might have yielded exactly such products as if submitted to dry distillation. *Anthracite* (§ 52) is justly considered as the result of the action of heat upon coal, since it contains as little oxygen and hydrogen as coke, from which it differs merely in its non-porosity, which is to be accounted for by the pressure to which it was subject during the process of its formation. The artificially-prepared coal-tar is replaced by *petroleum* or stone-oil (CH).

In many districts, particularly on the borders of the Caspian Sea, at Amiano in Italy, and at Rangoon in Burmah, an oily substance called *rock-oil*, or petroleum, is found to exude from the soil, and is met with floating on the surface of the water of springs. Some kinds are of a pale colour and very fluid, while others are dark and semi-solid at the ordinary temperature. The latter varieties when distilled yield a colourless naphtha which has the formula C_6H_5; its principal application is in the preservation of potassium, sodium, and the metals of the alkaline earths. The residue remaining after the volatile oil has passed off contains a considerable quantity of *paraffine*—a substance said to be obtained in considerable quantity in the distillation of Irish peat, and to be admirably adapted, when mixed with a suitable proportion of wax, to making candles.

In like manner naturally-formed tar, which has received the name of *asphalt* or *Jew's pitch* (bitumen), is found sometimes in an indurated condition, and sometimes more or less soft. This is employed for many purposes, particularly for tarring, as fuel, cement, black paint, or varnish for wood, iron, &c. Mixed with coarse sand it is used in the preparation of roofing-felt, and for paving,

flooring, &c. The artificially-prepared tar may be employed for similar purposes after it has been deprived of its oil by distillation with water.

Herewith we conclude our description of chemical phenomena, several of which have been but slightly noticed, and more not mentioned at all. To those who wish to study chemistry more profoundly, either for professional, artistic, or manufacturing purposes, we recommend the many excellent works on this subject in our own and the continental languages.



MINERALOGY AND GEOLOGY.

1. **Mineralogy** is the science which treats of **Minerals**, or those constituents of the earth which are of similar composition through their entire mass.

All parts of the same mineral are alike. In none of them do we observe those peculiar structures which we term *Organs*, and which, in Plants and Animals, fulfil functions that are indispensable to the existence of the individuals to which they belong. Minerals are consequently called *Inorganic* substances. It is immaterial whether the mineral subjected to examination

is large or small; in either case it presents to us the same structure. A small specimen of sandstone gives us as good an idea of its properties as would be given by a large block or a mountain of the same material. A rock crystal of the length of a line is as perfect as one a foot in length.

2. In Chemistry (§ 3 and § 9) we have already seen that the entire mass of the earth is composed only of a few more than 60 simple substances or elements. By virtue of the chemical affinity possessed by these bodies they are found to exist in the greatest variety of combination, and only seldom occur as simple substances. Proceeding from this view, Mineralogy might be termed the science of those chemical compounds which occur in Nature. We have already, in studying the science of Chemistry, become acquainted with a number of such natural compounds, and have mentioned the names of many others.

Chemical affinity, however, is not the only power by which the elements are influenced in the great laboratory of Nature. Its action is accompanied by that of a number of other forces and influences, producing a series of mineralogical formations which cannot be considered simply from a chemical point of view, nor explained by chemical affinity alone.

3. Minerals may, therefore, be classed in two principal groups, which are readily distinguishable from each other. Those of the first class possess all the properties of perfect chemical compounds; they are definite in their chemical composition, and equally definite in their crystalline form. These bodies are the true or *simple* Minerals, and the science that treats of them is MINERALOGY.

The other series of minerals has an essentially different character. The objects composing it are either evident mixtures of simple minerals, or, if they agree with simple minerals in chemical composition, they differ by having no definite crystalline form. Hence they do not occur as well-defined crystals, but in amorphous masses. These substances are called *Mixed Minerals*, *Stones*, or *Rocks*. The study of their properties, of their relations to each other and to the mass of the earth, and the investigation of their origin and mode of aggregation, constitute the subject of that division of natural science which is termed GEOLOGY.

I.—MINERALOGY.

4. The first condition required of Mineralogy is that it shall furnish us with means to recognise Minerals and determine the classes to which they belong. Minerals may be distinguished and classified by certain characteristics. These are, principally, 1, their *Form*; 2, their *Physical*, and 3, their *Chemical*, properties. With the aid of these characteristics we can make an attempt to describe minerals.

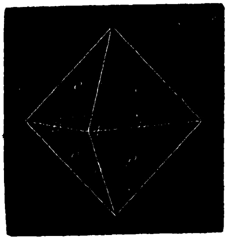
1. FORM OF MINERALS.—CRYSTALLOGRAPHY.

5. We have already remarked in Physics (§ 19), and in Chemistry (§ 29), that the smallest particles of chemical compounds attract each other and arrange themselves in certain directions, producing regularly-formed bodies, which are called *crystals*. These forms exhibit *faces* or *planes*; *edges* or lines of contact of two planes, and *points* or *angles* formed by the meeting of three or more planes. There is no form of crystal exhibiting less than four planes, six edges and four angles, and most crystals have a larger number.

As every mineral, with few exceptions, always crystallises in one definite primary form, the observation of the forms of minerals is naturally a very important and certain mode of discriminating them. The forms of crystals are, however, exceedingly numerous. On examining a collection of minerals, hundreds of different forms are presented to the eye; yet these varieties may be traced back to a few *fundamental forms*, from which they are all derived. Of these fundamental forms there are six, which, with the various secondary or derived forms, constitute six families or systems of crystallisation, the study of which forms a particular branch of science termed *Crystallography*. It is not possible for us to enter into the details of this science, but we will endeavour to make ourselves acquainted with the primary forms, with the most important secondary forms, and with the manner in which a secondary crystal is described and traced back to its fundamental form.

Fundamental Forms of Crystals.

6. The *regular octohedron* (fig. 1). This crystal is limited by eight equal equilateral triangles, and has twelve edges and six angles. An imaginary line, extending from one angle to the opposite one, represents what is called the *axis* of the crystal. The octohedron has therefore three such axes, which are all equal and intersect each other at right angles. The whole form of the crystal is dependent upon this relation of the axes. If we construct an axis-cross with three knitting-needles of equal length, so that they cross each other at right angles, their ends will represent the angles of a regular octohedron.



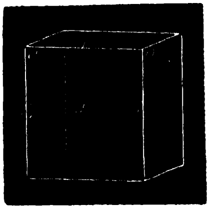
1.

Irregular octohedrons, which are likewise fundamental forms, may also be easily represented by such crosses. The axes are either of unequal length, or they do not intersect each other at right angles, or they may exhibit both of these deviations.

In examining and describing a crystal, it is always placed in such a position that one of the axes is situated vertically in front of the observer; this is called the *principal axis*, while the others are termed *secondary* axes. When the axes of a crystal are equal, any one may be adopted as the principal axis, but when they are unequal the longest is generally chosen as the principal.

7. The *secondary* forms of the octohedron, as of all other crystals, are produced by the real or imaginary removal of certain portions of the primary form in a regular manner. We will give a few examples of this, which may be rendered more lucid by the use of prepared models or by cutting the

2.



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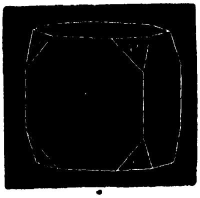
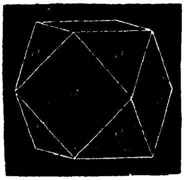
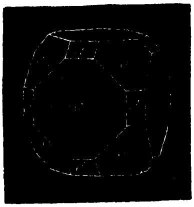
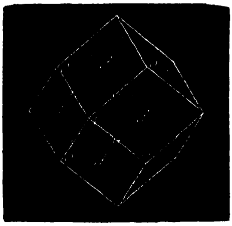


4.

requisite forms out of a piece of potato or turnip. On removing the angles from the octohedron (fig. 2.) by parallel sections, a cube will at last be obtained. The *cube*, or six-faced solid (fig. 3), has six square planes of equal magnitude, eight angles, and twelve edges. On removing the angles of this crystal, as in fig. 4, the regular octohedron is again obtained. The crystal



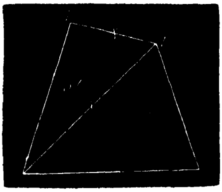




represented by fig. 5 is intermediate between those shown by figures 2 and 4, or between figures 1 and 3. It is evident that these forms bear certain definite relations to each other, and therefore they are said to belong to the same system of crystallisation, which has been called the *regular* system.

A number of secondary forms may be obtained by truncations that remove the angles and edges of the primary forms. Thus, fig. 6 is a cube deprived of its edges and angles. If the removal is continued in a regular manner the *rhombic dodecahedron* (fig. 7) is obtained, of which the twelve equal planes are rhombs.

Another series of secondary forms—the *hemihedral* forms—is produced by removing, not the whole of the angles or edges of a primary form, but only



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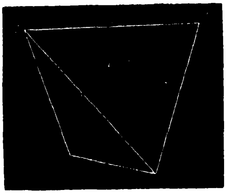

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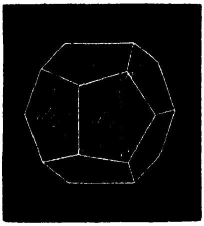


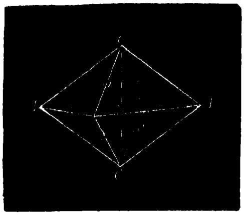
10.

the alternate angles or edges which are situated opposite to each other. The three-sided pyramid, or *tetrahedron* (figs. 8 and 9), is thus obtained from the octohedron. The *pentagonal dodecahedron* (fig. 10) is a secondary form obtained in a somewhat similar manner.

3. The *second* primary form is the *quadratic octohedron* (fig. 11): this form has three axes intersecting each other at right angles, two of which are equal, while the third is longer or shorter than the others. The middle section of this octohedron is a square. By truncation of its edges the prism (fig. 12) is obtained. The latter may again in various ways be pointed or have its edges and angles removed.

The *third* primary form is the *rhombic-octohedron* (fig. 13), the axes of which cross each other at right angles, but are all unequal. The middle section of this octohedron is a rhomb. This is one of the crystalline forms of sulphur. The rhombic *prism* is obtained by the truncation of the edges of the octohedron.

The *fourth* primary form is an octohedron with three axes of unequal length, two of which intersect each other at an oblique angle, but are pl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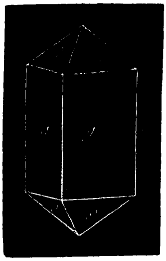
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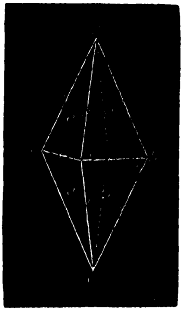
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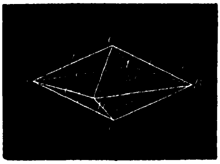
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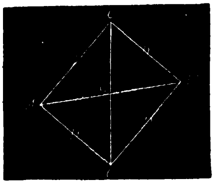
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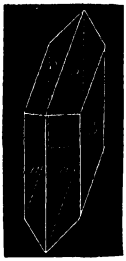
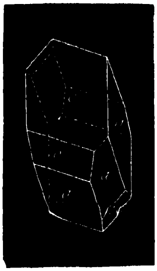

16.

t right angles to the third axis, as shown in figs. 14, 15. This octohedron enerally occurs in its secondary forms, particularly in oblique rhombic risms, as in gypsum (fig. 16).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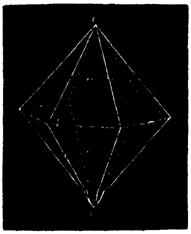
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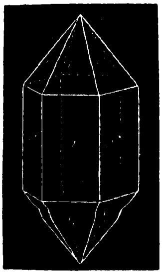
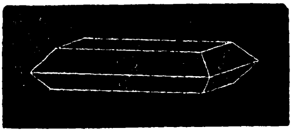

19.

The *fifth* primary form is an octohedron of which all the axes are unequal,

and intersect each other at oblique angles. This octohedron only occurs in its secondary forms, such as is exhibited by fig. 17, which is the crystalline form of axinite.

Figs. 20 and 21 represent two derived forms, which are not only of frequent occurrence in the mineral kingdom, but also in chemical preparations.



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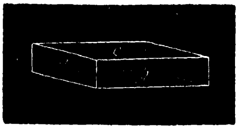
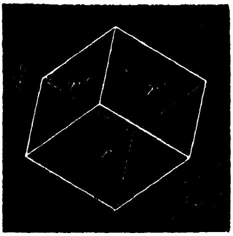


21.

These are the *tabular* crystals or plates, some of which have straight terminal planes, as fig. 21, while others are sharpened off at the sides, as fig. 20.



22.

The *sixth* primary form is the *hexagonal dodecahedron* (fig. 18), a double six-sided pyramid. This system, which is also termed the *hexagonal system*, is the only one which has four axes: three of these are equal, and intersect each other at acute but equal angles. The fourth or principal axis is unequal to the others and intersects them at a right angle. Among the secondary forms of this system may be mentioned the beautiful hexagonal prism (fig. 19), and the rhombohedron (fig. 22), which is enclosed by six equal rhombs.

9. The same mineral frequently occurs in very different crystalline forms, which, however, will always be found to belong to one and the same system, that is to say, they may always be traced back in some way or other to the same primary form. The determination of the form of the crystal is frequently attended with considerable difficulty. This arises in part from the similarity which many forms have to each other, so that they can frequently be distinguished only by the most accurate measurements of the edges and angles of the crystals. Sometimes the difficulty is caused by the crystals being very rarely so regularly and distinctly formed as they are represented in diagrams. In attempting to account for the irregularities of natural crystals, it may generally be assumed that there were obstacles present at the instant of their formation which did not permit the crystal to be equally and perfectly developed on all sides. Thus, it is frequently observed that only one-half, or only an edge, an angle, or a plane of the crystal is produced, the remainder of the form being either entirely wanting or hidden in an extraneous adhering mass (see the figure at page 238). The most regular forms frequently appear to be perfectly irregular, the necessary conditions for the formation of the crystal having been favourable only on one side. The difficulties attending the examination of crystals may, however, be overcome by practice. Models of crystals, which may easily be procured, are of great assistance in the study of crystallography.

A variety of familiar names are given to irregular crystalline formations, such as tables, plates, needles, &c.

A mineral appears as a *crystalline* mass, or aggregate, when it consists of small crystals irregularly and closely arranged together. Thus, for instance, calcareous spar is distinctly crystallised, and marble only crystalline, carbonate of lime. When a mineral exhibits no crystalline arrangement of its particles, it is said to be *amorphous.* Cavities in many masses of rocks are sometimes filled with groups of crystals. These are called *geodes* or *drusic cavities* (comp. § 81).

2. PHYSICAL CHARACTERS OF MINERALS.

10. As minerals cannot always be distinguished by their form, other characteristic properties are called into aid, such as the cohesion, the specific gravity, and the colour of minerals, also their comportment with light, electricity, and magnetism. These are termed the *physical characters* of minerals.

Cohesion.

11. There are only two liquid minerals; the greater number is solid, and with these special regard is to be paid to their cleavage, fracture, and hardness.

A mineral is *cleavable* when it is possessed of crystalline structure. In such a case its particles are arranged in a certain manner, so as to exhibit less cohesive power in one direction than in another, similarly to wood which is more easily cleavable in the direction of its fibre than across the grain. There are, of course, various degrees of *cleavability;* thus, mica is cleavable into the thinnest laminæ. Cleavage surfaces are more or less plane.

Fractures, or fractured surfaces, are produced by the forcible disintegration of minerals that are not cleavable, or of cleavable minerals in any other direction than that of their cleavage. The appearance of the fracture is very characteristic of many minerals; it is either *even* or *uneven*, or it may be *conchoidal*, as, for example, in the case of flint. It may be also *splintery*, or *jagged*, and very frequently it is *earthy*, as in chalk and many other minerals.

12. In the description of a mineral, particular attention is always paid to its *hardness.* Many minerals are sufficiently hard to resist the best files, while others are so soft as to admit of being scratched with the finger nail. There are between these two extremes various degrees of hardness, which cannot be so easily described. Other means have, therefore, been resorted to for the determination of the degree of hardness of different minerals with tolerable accuracy. Of two minerals, that one of course is the hardest which will scratch the other without being scratched itself. A scale of hardness has been constructed by Mohs, consisting of ten well-known minerals, so arranged that each one will scratch that which precedes it, and may be itself scratched by all those which follow it in the scale. Thus, ten degrees of hardness are obtained between the softest mineral, which is talc, and the hardest, namely diamond: these degrees are represented by the corresponding numbers; they are as follows:—

Degree of hardness	1=Talc.	Degree of hardness	6=Felspar.
	2=Gypsum or rock salt.		7=Quartz.
	3=Calcareous spar.		8=Topaz.
	4=Fluorspar.		9=Corundum.
	5=Apatite-spar.		10=Diamond.

If, therefore, the degree of hardness of a certain mineral is said to be 7,

we know it to be equal to that of quartz. It may easily be remembered that a high degree of hardness is represented by a high number, and *vice versâ*. The best way of trying the hardness of a mineral is to rub it on a hard fine-toothed file in comparison with the minerals that constitute the scale, pieces of which are reserved for that use. The scratching of minerals by one another is liable to several fallacies.

Specific Gravity of Minerals.

13. The density or specific gravity of a body, as was shown in Physics (§ 34), is the weight of a certain volume, compared with that of an equal volume of water. Thus, the density of lead is = 11, since one cubic inch of this metal weighs 11 times as much as 1 cubic inch of water. We have already spoken of the value of a knowledge of specific gravities; the fact of substances always possessing the same density under uniform circumstances, furnishes an important means of recognising them, particularly in the case of minerals. Hence the determination of their specific gravities has been made and repeated with the greatest care, generally at a temperature of 15°·5 C. (60° F.) From what has been said in Chemistry, it may in general be assumed that minerals of high specific gravity contain heavy metals.

Comportment of Minerals with Light.

14. As minerals are a very extensive and diversified class of bodies, they exhibit an exceedingly varied behaviour under the influence of the rays of light. Many minerals permit these rays to pass through them, and refract them during the passage. Others reflect the light in a peculiar manner. This leads us to speak of the transparency, the refracting power, the lustre, and the colour of minerals.

Transparency is either perfect or imperfect. We meet with the former chiefly in highly-developed crystals. Sometimes this character (perfect transparency) appears in conjunction with the absence of colour, in this case the mineral is termed simply *transparent*. The different degrees of imperfect transparency are indicated by the terms *semi-transparency* and *translucency*. The term *opaque* is employed where no rays of light are transmitted by the mineral.

Refracting power (Phys. § 161) is only perceptible in perfectly transparent crystals. It varies exceedingly in different minerals; thus the precious stones are highly refractive, while other minerals possess this property only in a slight degree. *Double refraction* is a very peculiar phenomenon. Many minerals not only refract the incident ray, but divide it into two parts, each proceeding in a different direction, so that two images are seen of any object, such as a black line, when viewed in a certain direction through the crystal. Iceland spar is a mineral which exhibits this double refractive power with great distinctness.

15. The *lustre* of minerals is dependent on the nature of their surfaces; and the more these approximate to the reflecting surfaces of mirrors, the more perfect is the lustre. Minute flaws and inequalities, all give rise to certain peculiarities of lustre, which are expressed by various intelligible terms, according to their nature and vividness.

Thus we distinguish: *metallic lustre*, *adamantine lustre*, *vitreous lustre*, *waxy* or *fatty lustre*, *pearly* or *nacreous lustre*, and *silky lustre*. Some minerals are also described as *highly lustrous*, *lustrous*, *slightly lustrous*, *shining*, and *dull*; those of earthy fracture, for instance, are distinguished by the latter term.

The *colours* of minerals are expressed by the terms generally adopted for denoting the impressions they produce on the eye. The principal colours are *white*, *gray*, *black*, *blue*, *green*, *yellow*, *red*, and *brown*; besides these there is a variety of mixed colours of all possible shades. A scale of colour, similar to the scale of hardness, has been constructed, the colour of a certain mineral being distinguished by a particular name.

The *streak* of a mineral is also a remarkable characteristic; it is the colour produced by rubbing or streaking a mineral on a white body, or by scratching it with a harder substance. The streak is, generally speaking, lighter than the colour of the mineral, thus, for example, manganite is nearly black, whilst on paper it produces a brown streak. The colour of a mineral often agrees with that of its streak, yet highly-coloured minerals frequently yield very pale or even colourless powders. The streak of a mineral, or the colour of the powder produced by scratching it, affords a more trustworthy character than its external colour.

There are many other phenomena of colour, such as *opalescence* and *iridescence*, which, however, occur less frequently. Some minerals under certain conditions, for instance when they are heated, or exposed for some time to the rays of the sun, possess the property of becoming slightly luminous when placed in the dark. This property is called *phosphorescence*, and may be observed by heating pulverized fluorspar on a platinum knife in the flame of a spirit-lamp.

Comportment of Minerals with Electricity and Magnetism.

16. Physics has taught us (§ 175) that all bodies are classed into two groups, one comprising those that become electrical by friction, which are therefore called *electric bodies*, the other formed of those bodies that do not exhibit this property, and which are therefore termed *non-electric bodies*. The electric bodies are non-conductors, and the non-electric bodies are conductors of electricity. It may readily be ascertained to which group a mineral belongs, by rubbing it, and then approaching it to an electrometer. Generally speaking, those minerals that contain heavy metals belong to the class of non-electrics or conductors, while minerals that consist of the non-metallic elements, and of the compounds of the lighter metals, become electric by friction, and are non-conductors or imperfect conductors of electricity.

Comparatively few minerals, and only those which contain iron (comp. Phys. § 192) exhibit *magnetic* properties. The magnetic deportment of a mineral may easily be detected by placing it in juxtaposition to a magnetic needle.

Odour, Taste, and Touch of Minerals.

17. Most minerals have no *odour*. Some have a very characteristic odour, which generally arises from the presence of foreign substances, particularly of mineral naphtha (Chem. § 171); sometimes, however, the odour becomes perceptible only on striking, rubbing, or breathing on the mineral. Several

minerals, such as those containing sulphur and arsenic, evolve peculiar odours when heated, these odours being due to chemical changes.

Taste is only possessed by such minerals as are soluble in water, of which there are comparatively few. Its nature is of course dependent on the composition of the mineral; thus the taste of rock-salt is *saline*, that of salts of magnesia *bitter*, that of nitrates *cooling*, &c.

The *touch*, or perception experienced on handling many minerals, is very characteristic, some being *rough*, as lava; others *fatty* or *unctuous*, as soapstone or talc, whilst others, such as the precious stones, produce a sensation of *cold* when touched. Several minerals possess the property of absorbing water, and some with such power as to adhere firmly to the tongue or a moistened finger, when brought in contact with it; clays exhibit this property in a remarkable degree.

3. CHEMICAL PROPERTIES OF MINERALS.

18. As we have already described minerals as chemical compounds occurring in Nature, they must necessarily be possessed of properties bearing a certain relation to their constituents, and becoming particularly evident when the minerals are decomposed. Chemical formulæ are employed with great convenience in distinguishing those minerals which have a definite chemical composition. It is therefore of advantage to have become already acquainted with Chemistry, since in Mineralogy we have to refer to that science at every step.

When structure and physical characteristics are insufficient to enable us to recognise a mineral or determine its nature, we must have recourse to chemical tests. The Mineralogist has then to solve two problems by means of Chemistry; first, the *nature* of the substances contained in the mineral, and then the *quantity* in which each substance is present. To arrive at a knowledge of the latter it is necessary to effect a perfect separation of the mineral into its constituents, and to weigh them. This operation is called *quantitative analysis*, and requires much time and care.

Qualitative analysis merely makes us acquainted with the various substances contained in a body, and, generally speaking, may be conducted with greater expedition, particularly by the Mineralogist, who has other auxiliary means at his disposal for recognising a mineral. He therefore confines himself, as far as possible, to the most simple chemical agents, which he can easily take about with him, and have continually at command. He avails himself especially of the decomposing power of *heat*, and the solvent property of *water* and *acids*. The submission of a mineral to the former is termed its investigation in the *dry way*, and to the latter its examination in the *moist way*.

ACTION OF HEAT ON MINERALS.

19. The Mineralogist applies heat in various degrees of intensity, from gentle warming to the most powerful ignition. For the latter purpose he makes use of the *blowpipe*, which is a tube of metal, terminating in a point with a narrow orifice. The opposite end is called the mouth-piece, because it is placed in the mouth, and by means of which air is forced through the blowpipe. The latter is made 7 or 8 inches in length, and is somewhat bent at the extremity. On forcing, by means of the blowpipe, a jet of air into

the flame of a lamp, we obtain on a small scale the same effect which the Smith produces by the bellows of the forge, namely, an intense heat in a confined space. The blowpipe imparts to the flame a conical form; into this flame small fragments of the mineral to be examined are introduced, being either held by a small pair of forceps with platinum points, or placed upon a piece of well-burnt charcoal. When the specimen is to be only gently heated, it is frequently heated in a glass tube by means of a spirit-lamp without the aid of the blowpipe.

20. In performing these experiments, the particular points to which attention is directed are the fusibility and volatility of the substance, as also the particular colour which it may impart to the blowpipe flame.

The *fusibility* of minerals varies exceedingly. Some fuse at a gentle heat in the ordinary flame of a lamp, as many salts, for instance; others are fused only by the application of the most intense heat; and some are perfectly infusible. The different degrees of fusibility are expressed by the terms easily fusible, difficultly fusible, infusible, &c.

The fusion of substances is attended by other phenomena worthy of notice; thus some minerals fuse quietly, others swell up or intumesce, or decrepitate, &c. The fused mass either presents itself in the form of a glass, a slag, a scoria, an enamel, or a metallic bead, the latter being generally formed when a heavy metal is present.

Volatile substances are very often expelled from minerals by the application of heat. Thus aqueous vapour is almost always evolved, and it is necessary to observe whether this water be merely accidental, or chemically combined as water of hydration or of crystallisation (Chem. § 28). Many minerals disengage various gases, as, for instance, chalk evolves carbonic acid, and binoxide of manganese evolves oxygen. New compounds are often produced during ignition, by the combined action of heat and the oxygen of the air. Thus, lead ores become easily coated with a yellow crust of oxide of lead, ores of antimony with white oxide of antimony, sulphuretted ores yield sulphurous acid, which is easily recognised by its suffocating odour, and arsenical ores evolve the peculiar garlic odour of arsenic.

The *colour of the blowpipe flame* is often an excellent means of distinguishing a mineral. Thus strontia imparts to the flame a crimson tint, lime an orange, potassa a violet, soda a bright yellow, boron and copper a green tint, &c.

21. Hitherto we have spoken of the influence of heat alone upon the substances under examination; frequently the co-operation of chemical substances is employed, by which peculiar phenomena are produced. Such substances are carbonate of soda, cyanide of potassium, and borax or biborate of soda.

We have already seen in § 20 that the oxygen of the air exerts an oxidising influence, and it must here be remarked, that the point of the blowpipe flame is the only portion which allows the oxygen to have access to the substance, this part of the flame is therefore called the *oxidising flame* of the blowpipe. If the substance under examination is introduced into the wide interior portion of the flame, which is not luminous, and still contains unconsumed carbon, the latter exercises a reducing action, if the substance contains an oxygen compound. This portion of the flame is hence called the *inner* or *reducing flame.* Thus, for instance, a piece of tin may be easily converted

into white oxide in the outer flame, and reduced again to a metallic bead in the inner flame.

22. Carbonate of soda and borax, when added to the specimen under examination before the blowpipe flame, are called *fluxes*, since they produce easily fusible compounds. Carbonate of soda when fused with compounds rich in silica forms an easily fusible soda-glass; it likewise serves for the production of soluble salts of arsensic, sulphur, manganese, &c., these elements when present being converted into acids by exposure to a high temperature. In the use of borax (biborate of soda, Chem. § 62), the boracic acid which resists the action of fire, combines with metallic oxides, forming peculiarly coloured glasses, which correspond pretty well in their colours with those of the glass fluxes with which we have previously become acquainted (Chem. § 77). The result obtained in this experiment is dependent on the part of the flame in which the fusion is effected, since the lower oxides frequently yield glasses which differ in colour from those produced by the higher oxides, as is shown by the following examples.

Oxides of	Colour of the Borax Glasses.	
	In the Oxidising Flame.	In the Reducing Flame.
Chromium,	Emerald-green,	Yellowish-brown, colourless on cooling.
Manganese,	Violet,	Colourless,
Antimony,	Bright yellow,	Dull and grayish.
Bismuth,	Colourless,	Gray and dull.
Zinc,	Colourless, a white enamel with much zinc,	Volatilises.
Tin,	Colourless,	Colourless.
Lead,	Yellow, colourless on cooling,	Reduced to metallic globule.
Iron,	Dark red, becoming lighter and nearly colourless on cooling,	Bottle-green, blue-green.
Cobalt,	Blue,	Blue.
Nickel,	Reddish-yellow, lighter on cooling,	Grayish.
Copper,	Bluish-green,	Colourless, cinnabar-red, and opaque on cooling.
Silver,	Milky white on cooling,	Grayish.

23. If we finally avail ourselves of the co-operation of water and acids as solvents of minerals, we enter at once into the range of those chemical phenomena which are described in all their details in special works on analytical chemistry.

It therefore only remains to be observed, that these solvents are generally applied in a certain order; namely, water first, then hydrochloric acid, then nitric acid, and finally a mixture of the two latter (Chem. § 36). Hydrochloric acid is most frequently employed, in order to ascertain whether the minerals effervesce; that is, whether they contain carbonic acid, which escapes as gas when the mineral is treated with this acid.

24. We have now made ourselves acquainted with all the preliminary knowledge required to enable us to proceed to describe Minerals. It must, however, be remarked, that of all sciences there is none in which mere description has been found so inadequate as in Mineralogy. In this science

personal observation is absolutely necessary. The object proposed is not a purely theoretical knowledge of minerals, but a practical acquaintance with them, which is only attainable through the medium of our senses.

It is, therefore, advisable that the student who intends to engage in the pursuit of Mineralogy should avail himself of those minerals which are furnished by the country in which he is living. Even the poorest districts have some minerals, and the examination of these will aid him in forming a conception of others. It is by no means difficult to obtain gradually the most important minerals by exchange or purchase, and thus to form a small collection. Small systematic collections of specimens of minerals can now be purchased for a trifling sum. In all institutions where this branch of natural science is embraced in the course of study, it is necessary above all things to excite an interest for the science by the aid of a collection of the most important minerals. In the study of natural history, the best description may be considered merely as a crutch, which is cast aside as soon as the student has an opportunity of inspecting the objects personally.

CLASSIFICATION OF MINERALS.

25. A mineral which may be distinguished from all others by its peculiar chemical composition and its properties is acknowledged as a distinct *Species*. The number of minerals thus established is very great, and is still increasing.

Minerals may be arranged according to various systems. Either their form is principally considered, and they are then arranged according to the systems of crystals, or their arrangement is based upon their density and hardness. Since, however, it has been more clearly shown that all these properties are dependent on the chemical constitution of the minerals, the latter has become the principal guide to their arrangement. In this classification particular regard is paid to that constituent which either predominates in quantity, or in its particular character, and which therefore furnishes the name for the group. The order of succession of the minerals in this arrangement is nearly the same as that of the elements and their compounds in Chemistry, although gaps are found to exist here and there in the system.

The acquirement of a knowledge of Chemistry is of course presupposed; by that knowledge a number of difficulties will vanish which would render the study of Mineralogy, according to outward characteristics alone, exceedingly laborious.

26. The nomenclature of minerals has been formed gradually, without any scientific basis, and is consequently imperfect. The names of genera and species are derived from many sources; as, for example, from popular or vulgar names, from the locality where they were first noticed, and from the names of celebrated naturalists; but few names have been derived from the properties and chemical constituents of the minerals. An alteration in the nomenclature cannot, however, be effected without giving rise to the greatest confusion; therefore the old names are retained as a matter of convenience, just as, in Chemistry, the names water and potash are still employed, instead of the more systematic names of oxide of hydrogen and oxide of potassium.

4. DESCRIPTION OF MINERALS.

27. A considerable space would be required for the description of all the minerals that are now known. We must therefore content ourselves with

describing the most important, and even these only briefly. A sufficiently detailed account has been given in the chemical section of this work, of several, as, for instance, of the different kinds of coal: of these, therefore, the mere enumeration will suffice.

Most of the simple minerals occur in comparatively small quantities, though some which are aggregated in large masses form a considerable portion of the earth's crust. These will be referred to in the chapter on Rocks.

In the following descriptions, H. signifies the hardness, and Sp. Gr. the specific gravity of the minerals:—

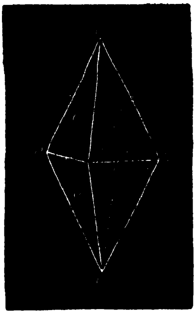
SYNOPTICAL TABLE OF MINERALS.

1st CLASS. METALLOIDS.	2d CLASS. METALS.		3d CLASS. ORGANIC COMPOUNDS.
	1st Order. Light Metals.	2d Order. Heavy Metals.	
Group.	Group.	Group.	Group.
1. Sulphur.	5. Potassium.	13. Iron.	29. Salts.
2. Boron.	6. Sodium.	14. Manganese.	30. Earthy resins.
3. Carbon.	7. Ammonium.	15. Cobalt.	
4. Silicium.	8. Calcium.	16. Nickel.	
	9. Barium.	17. Copper.	
	10. Strontium.	18. Bismuth.	
	11. Magnesium.	19. Lead.	
	12. Aluminum.	20. Tin.	
		21. Zinc.	
		22. Chromium.	
		23. Antimony.	
		24. Arsenic.	
		25. Mercury.	
		26. Silver.	
		27. Gold.	
		28. Platinum.	

FIRST CLASS.—MINERALS OF THE METALLOIDS.

1st GROUP—SULPHUR.

28. The primary form of crystallised sulphur is the rhombic octohedron occurring with various truncations of the edges and angles (figs. 23, 24). Sulphur occurs also frequently in the crystalline or granular, and the earthy state, and less frequently in the fibrous condition. Its cleavage is imperfect; its fracture conchoidal and uneven; H $=$ 1·5 to 2·5; it is brittle and fragile; Sp. Gr. $=$ 1·9 to 2·1. The chemical properties of sulphur and its application have been described in the section Chemistry (§ 40.)



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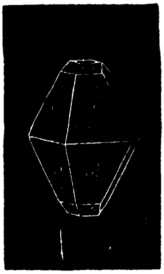


24.

The most important locality of sulphur is Sicily, where it is found

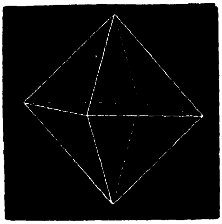
in the tertiary formations, associated with calcareous spar and celestine; at Girgenti, Fiume, &c. The strata of earthy sulphur in Poland are likewise very considerable. In addition to these localities, there are many places in Germany and the rest of Europe, as also in other parts of the globe, where sulphur is found. But the sulphur derived from these sources is far less pure than the sulphur of Sicily.

2D GROUP—BORON.

29. This element occurs rarely and only in combination with oxygen, as Boracic acid ($BoO_3 + HO$), which crystallises in scales, and is found as a crust upon the surface of the earth in the neighbourhood of volcanic springs. It is friable, of Sp. Gr. = 1·48, translucent, white, bitter and acid to the taste; it is easily fusible, and imparts a green colour to flame; it is soluble in water and alcohol. Boracic acid is deposited at the margin and at the bottom of volcanic springs or lakes, particularly in those of Sasso (hence the name Sassolin), Castelnuovo, and others, in Tuscany.

3D GROUP—CARBON.

30. (1.) *Diamond.*—This mineral occurs crystallised in regular octohedrons, or in some of the geometrically allied forms (figs. 25, 26, 27). It is possessed



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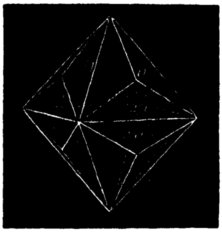

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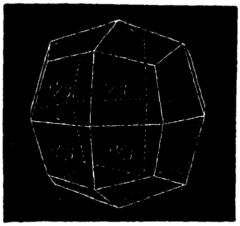


27.

of the greatest hardness, which is = 10; Sp. Gr. = 3·5 to 3·6; it is mostly cleavable, transparent, generally colourless, highly lustrous, refracts light very powerfully, and is the most valuable of all the precious stones. It occurs principally in alluvial soil and in rocks of secondary formation, in the East Indies (Golconda), and in Brazil. It has also lately been discovered in the sands of the rivers which have their sources in the Uralian mountains. 1 carat (= 4 grains) of small diamonds, employed for polishing the larger ones, for cutting glass, &c., costs from 20*s.* to 25*s.* A polished diamond (brilliant) weighing 1 carat, is valued at from £8 to £10; the prices of diamonds increase to such an extent with their size, that a brilliant weighing 5 carats may cost as much as from £150 to £250.

(2.) *Graphite* (Plumbago) is found in tabular crystals, belonging to the hexagonal system, but generally it occurs in scales and small laminæ. H = 1 to 2; Sp. Gr. = 1·8 to 2·4; it is cleavable, steel-gray to black, unctuous to the touch, and produces a black streak. It is found embedded in various rocks at Passau, in Bavaria; the finest quality, however, is met with at

Borrowdale, in Cumberland. The graphite from the former place is generally employed for crucibles and for blacking stoves, and that from the latter locality for the best black-lead pencils.

(3.) *Anthracite* occurs in large masses, having a conchoidal fracture. H $= 2$ to 2.5; Sp. Gr. $= 1{\cdot}4$ to $1{\cdot}7$; it is grayish-black, and leaves but little ash when burned. It is found in strata, occasionally of very considerable thickness, in the primitive rocks; as, for instance, in Wales and in the Hartz mountains. It is employed as a fuel for strong blast or wind furnaces, &c.

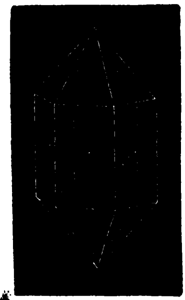
Coal, *brown-coal*, and *turf* must be mentioned as varieties of carbon, since this element forms their chief constituent. Their most important characters and properties have already been detailed in § 165 of Chemistry. We shall, however, more minutely describe the nature of their stratification in the chapter on Geology.

4th Group—SILICIUM.

31. By the term silica the Mineralogist designates the compound which chemists call silicic acid (SiO_3, Chem. § 61). The number of siliceous minerals is exceedingly large; silica, however, generally occurs in combination with alumina, hence the greater number of silica compounds is mentioned in the alumina group. It may in general be remarked, that the hardness of the purer kinds of silica is very considerable, sometimes amounting to $8{\cdot}5$; hence it produces sparks when struck with steel, whilst its specific gravity rarely exceeds $4{\cdot}5$. It possesses mostly a vitreous lustre, its prevailing colour being white. Silica when chemically pure, or merely coloured by small quantities of different oxides, is termed *quartz*.

Quartz Family.

The crystals of this family belong to the hexagonal system, and occur most frequently as double six-sided pyramids (fig. 18), but which are generally subjected to the modifications and irregularities spoken of in the article on Crystallography, and in part represented in the figures 28 to 31.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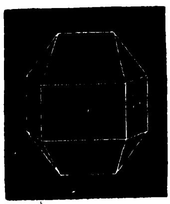
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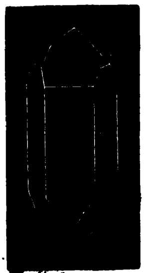
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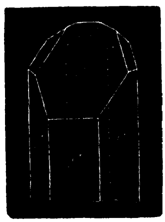

31.

Quartz also occurs frequently in crystalline, compact, or granular masses. Its fracture is conchoidal; $H = 7$; Sp. Gr. $= 2{\cdot}5$ to $2{\cdot}8$. It is either perfectly transparent, or white; it occurs likewise of all colours, and of every possible shade. It is insoluble in all acids, with the exception of hydrofluoric

acid (Chem. § 39); it yields with carbonate of soda, before the blowpipe, a transparent *glass;* and when struck with steel it produces brilliant sparks. The following are the principal varieties of quartz:—

(1.) *Rock crystal* (fig. 28), which is found in beautiful, transparent, six-sided prisms of considerable size, in the various primitive mountains. The crystals obtained from the caverns of St. Gotthardt are remarkably fine; they have also been found of extraordinary size and purity in Madagascar, where blocks of from 15 to 20 feet in circumference occur. Rock crystal is employed in jewellery, and as a constituent of pure glass fluxes. It is often slightly coloured, and frequently contains various foreign minerals, either in small scales or in other forms.

(2.) *Amethyst* is quartz that is more or less intensely coloured by protoxide of manganese. It occurs rarely in perfectly formed crystals, but more frequently as crystals lining drusic cavities. It is often found in the cavities of porphyry and amygdaloid, and, as it is by no means a rare mineral, is extensively employed as a jewel of small value. The amethyst was worn by the ancients as a charm against drunkenness.

(3.) Silica is called *common quartz*, when it does not occur in regular crystals, but only crystalline, granular, and compact. In this state it is often found in considerable masses which are called *quartz rock;* it also forms with other minerals mixed rocks, of which granite offers a familiar example.

It is very extensively dispersed over the surface of the earth. Its purer kinds are employed in the manufacture of glass, porcelain, &c. It is generally white and translucent; some varieties of it, altered in colour or otherwise, have received different names, as *rose quartz;* the blue variety, *siderite; schiller-spar; cats-eye*, so called from its peculiar iridescence; and *avanturine*, containing yellow and reddish laminæ of mica, which render it a very beautiful and ornamental stone.

(4.) *Calcedony* is an opaque kind of quartz, occurring in spherical, botryoidal, and nodular masses, possessing the most varied colours and curious markings. It is employed extensively for making snuff-boxes, buttons, marbles, &c. Red or yellow-coloured calcedony is called *carnelian*, and the green-coloured, *chrysoprase;* both are much prized for seals, and other raised and engraved ornamental works of art.

(5.) *Flint*, the properties of which are well known, is found in large irregular masses, in many parts of England and about Paris. Its application as a promethean apparatus has diminished considerably since the invention of lucifer-matches and percussion-caps. It is extensively used in potteries.

(6.) *Hornstone* is a variety of quartz somewhat similar to flint, but has a more splintery fracture, and bears a remarkable resemblance to horn.

(7.) *Jasper* is opaque, dull, and only slightly lustrous, on account of the larger amount of alumina and oxide of iron which it contains. It occurs of all colours; but red, yellow, and brown are most frequent.

(8.) *Siliceous slate* is a mineral consisting of quartz, alumina, lime, and sesquioxide of iron, coloured black by carbon; it is employed as a whetstone and touch-stone (Chem. § 107).

(9.) *Agate* is, generally speaking, a beautifully-marked mineral, consisting of a mixture of various kinds of quartz, particularly of amethyst, calcedony, and jasper. It is extensively employed by lapidaries for making a variety

of ornamental objects, and also for mortars, which are employed for pulverising very hard substances.

Opal.

32. This mineral is a particular variety of quartz, containing water in chemical combination. It does not occur crystallised, but mostly in compact vitreous masses, and is distinguished by the brilliant and changeable reflections of light exhibited by some of its varieties; whence the term *opalescent* is derived. *Noble opal* possesses this property in a very high degree, and is therefore much prized as a jewel. *Semi-opal*, or *common opal*, is less remarkable for its changes of colour. *Hydrophane* is a mineral, possessing the peculiar property of becoming transparent and iridescent only when moistened with water.

Siliceous sinter and *mountain meal* are likewise varieties of quartz, containing water; the former is deposited in a variety of forms by hot springs, particularly by the Geyser of Iceland. The latter is an earthy deposit from siliceous waters, and, when examined under the microscope, is found to consist almost entirely of the shells of infusoria. Another kind is called *polishing slate*, and is employed by lapidaries for polishing stones.

SECOND CLASS.—MINERALS CONTAINING METALS.

FIRST ORDER—LIGHT METALS.

5th Group—POTASSIUM.

33. The most important and indeed the greater number of minerals containing potassium likewise contains alumina as an essential constituent: we shall therefore describe them in the aluminous group. Of natural potassa salts, we have only to mention the nitrate and the sulphate of potassa.

Nitrate of potassa, or *nitre* (KO,NO_5), crystallises in regular rhombic prisms, but it is found, in many localities, in the form of crusts of acicular and capillary crystals (comp. Chem. § 69).

Sulphate of potassa (KO,SO_3) belongs to the same crystalline system, and is found occasionally in volcanic lavas.

6th Group—SODIUM.

34. (1.) *Nitrate of soda* (NaO,NO_5) crystallises in the hexagonal system as obtuse rhombohedrons, and occurs in crystalline masses of considerable magnitude; which, in the districts of Atakama and Tarapaca, in Peru, extend over a space of nearly 200 miles.

(2.) *Rock-salt*, chloride of sodium ($NaCl$), crystallises in the cubical system; it generally occurs, however, in tabular crystalline masses, and is easily cleavable in a direction parallel to the planes of the primary form; its fracture is conchoidal, $H = 2$; Sp. Gr. $= 2{\cdot}2$ to $2{\cdot}3$; its colour is generally white, but it is also found of a red, green, yellow, and blue colour; its chemical properties and its applications are detailed in Chemistry § 72. Rock-salt occurs in secondary Rocks, in masses of considerable magnitude, often in company with gypsum, alumina, and saline clay. The salt-works of Cheshire, of Hallein in Saltzburg, and of Wielizka in Gallicia, are particularly celebrated: in the latter is found the *decrepitating salt*, which dissolves in

water with a decrepitating noise and disengagement of numerous bubbles of hydrogen gas. The gas is enclosed between the crystalline planes of the salt. A number of other minerals containing soda are found, but are of less importance than the foregoing. Of these may be mentioned anhydrous and hydrated sulphate of soda (Thenardite $=$ NaO,SO_3, and Glauberite $=$ NaO,SO_3+10HO); carbonate of soda, containing a large quantity of water (NaO,CO_2+10HO), and another kind containing less water, called *trona* ($2NaO,3CO_2+4HO$), which occurs in the interior of Barbary in considerable quantities, as a crust on the earth, and is applicable to the same purposes as soda.

Biborate of soda ($NaO,2BoO_3+10HO$), as a mineral, is called borax or tinkal, and is found at the bottom and on the borders of a lake in Thibet.

7th Group—AMMONIA.

35. Since the combinations of ammonia, as we have seen in § 78 of Chemistry, are of a volatile nature, they occur only in inconsiderable masses, though not unfrequently, in the mineral kingdom. They are met with principally as crystalline coatings or crusts; for instance, in cavities and the fissures of lava of active volcanoes, in brown-coal works, particularly in the neighbourhood of burning and spent heaps of coals.

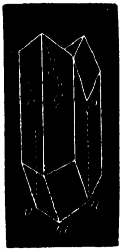
8th Group—CALCIUM.

36. This metal forms an extensive group of minerals, which possess a low degree of hardness and density, and are generally of a pure white colour. The most remarkable are—

(1.) *Fluorspar* ($CaFl$), which crystallises in various forms of the regular system, but most frequently as cubes. It is perfectly cleavable; its fracture is conchoidal; $H = 4$; Sp. Gr. $= 3{\cdot}1$ to $3{\cdot}17$; it is transparent and partly translucent; it seldom occurs white, being generally tinted faintly violet, green, yellow, &c. In reference to its chemical properties, see Chemistry, § 39. Fluorspar is a mineral of frequent occurrence, though never in considerable masses. The same mineral occurs amorphous, as *compact fluor* and as *earthy fluor.*

(2.) *Anhydrite* (CaO,SO_3), or anhydrous sulphate of lime, is found generally in the neighbourhood of gypsum and rock-salt. It occurs crystallised, and also in radiated, granular, and compact masses.

(3.) *Gypsum* (CaO,SO_3+2HO), or hydrated sulphate of lime, occurs most frequently in tabular crystals, which may be cleaved into very thin laminæ; they belong to the system of the fourth primary form (fig. 16); $H = 2$; Sp. Gr. $= 2 = 2{\cdot}4$. It frequently occurs in double or twin crystals, of the form represented in fig. 32. It is possessed of double refractive power, vitreous lustre, and generally has a white colour. This kind of gypsum is called *selenite;* there are, besides, other varieties, viz., *fibrous* gypsum; *compact* or *granular* gypsum, which is called *alabaster*, and *earthy* gypsum. Regarding its application, see Chemistry, § 81.



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(4.) *Apatite*, sometimes called asparagus-stone, on account of its beautiful pale green colour, consists of phosphate of lime, fluoride and chloride of calcium. It crystallises in the

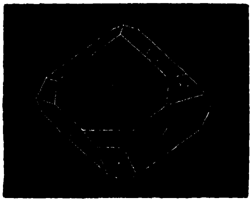
hexagonal system, often like fig. 41, and is frequently embedded in various kinds of rocks.

(5.) *Pharmacolite* is arseniate of lime ($=CaO,AsO_5$).

(6.) Carbonate of Lime (CaO,CO_2).

37. This mineral exhibits the remarkable peculiarity of crystallising in forms belonging to two different systems; hence its varieties form two families, namely, those of Calcareous spar and of Arragonite.

(1.) *Calcareous spar* crystallises in the hexagonal system, and more particularly in modifications of the rhombohedron (fig. 22). These modifications, however, are so exceedingly numerous, that 700 different forms have already been observed. Figures 33 to 39 represent some of the chief forms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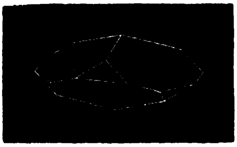
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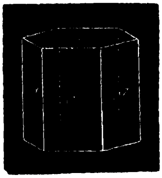
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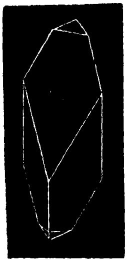
of carbonate of lime, which we shall briefly describe, as they give much insight into the mysteries of crystallography. Fig. 33, *r* shows the planes of the primitive rhombohedron (obtainable from *all* the crystals of calcareous spar by cleavage), combined with $r\frac{1}{2}$, a more obtuse rhombohedron, and $r2$, a more acute rhombohedron. In fig. 34, the primary rhombohedron, *r*, is almost entirely obliterated by the large planes of the obtuse rhombohedron, $r\frac{1}{2}$. In fig. 35 we have a regular six-sided prism, such as forms the middle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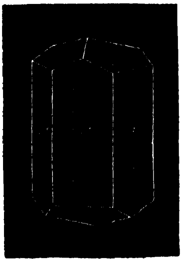
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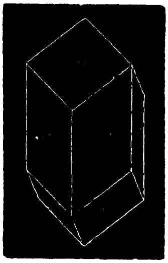
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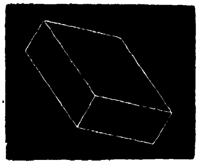

39.

portion of the crystal represented by fig. 19. Fig. 36 represents small faces of the primitive rhombohedron, *r*, combined with a predominant and very acute rhombohedron, $r4$. In fig. 37 we have the obtuse rhombohedron, $r\frac{1}{2}$, terminating a regular six-sided prism, *g* (fig. 35), and in fig. 38 the inverse, but equal six-sided prism, *a*, terminated by the regular rhombohedron, *r*. Crystals of all these forms are readily procured among the minerals of Cumberland and Derbyshire.

Fortunately the other properties of calcareous spar are such as to admit of its easy recognition. It is very easily cleavable into the primitive rhombohedron (fig. 20), and into tables such as shown by fig. 45. It has a conchoidal, splintery, and uneven fracture; H = 3; Sp. Gr. = 2·6 to 2·17; it becomes electric by friction, is soluble in the mineral acids with evolution of carbonic acid, and is converted by exposure to a red heat, into caustic lime (Chemistry, § 79). Its varieties are:—

(*a.*) *Crystallised calcareous spar*, called also *double refracting spar*, because it is possessed of double refractive power in a high degree (§ 14). It most generally forms tabular, transparent, colourless crystals of vitreous lustre, frequently occurring in all varieties of formations, particularly in drusic cavities. The double refracting spar found in Iceland is celebrated for its beauty. (*b.*) *Fibrous limestone*, which occurs principally in stalactitic formations, in the cavities of chalk-hills. (*c.*) *Marble*, or granular carbonate of lime, which is most esteemed when it is perfectly white, fine-grained, compact, and free from coloured veins. It is employed in that state by sculptors for their most beautiful productions. The most celebrated marble quarries are those of Carara, in Italy, and of Paros, in Greece. Coloured marble, frequently containing variegated spots and veins, is much more common; it is employed for pedestals, columns, &c.: it is one of the most beautiful building materials, and is often imitated by coloured and polished gypsum (stucco). (*d.*) *Schiefer-spar.* (*e.*) *Aphrite*, or *earth-foam.* (*f.*) *Compact limestone*, in which no crystalline structure is perceptible, and which generally occurs in large masses, forming entire limestone hills. It is found in all later mountain formations, in the most varied forms and colours, as *stinkstone*, *marl*, *oolite (Roestone)*, *calcareous tufa*, &c. (*g.*) *Chalk*, well known as the fine earthy white writing material, occurring in masses in the tertiary formations, particularly in England and in France (Champaigne).

(2.) *Arragonite*, the crystals of which belong to the rhombic system (fig. 13), and generally occur as rhombic prisms. The crystals are sometimes isolated, and often grown together, groups being thus frequently produced, which have the appearance of hexagonal prisms. Arragonite is cleavable; its fracture is conchoidal and uneven; H = 3 to 4; Sp. Gr. = 2·9 to 3; it is transparent, vitreous, and colourless. It is not unfrequently found in the vesicular cavities of basalt and other rocks. It occurs in groups of hexagonal prisms in Arragon, whence its name is derived. Besides crystallised arragonite, we also find radiated and fibrous arragonite.

9TH GROUP—BARIUM.

38. (1.) *Heavy spar*, or sulphate of baryta (BaO, SO_3), crystallises in rhombic prisms, of which about 73 modifications have been observed; fig. 40 represents one of the tabular forms in which this mineral crystallises. It is perfectly cleavable, and exhibits an imperfect conchoidal fracture; H = 3 to 3·5; Sp. Gr. = 4·3 to 4·58, whereby it is easily distinguishable from similar spathic minerals. It is transparent, and possesses double refractive power and vitreous lustre; it

40.

imparts a green colour to the blowpipe flame. A piece of heavy spar, when heated or ignited, will remain luminous in the dark for some time afterwards.

Crystallised *heavy spar* is of frequent occurrence in mineral veins. It is employed as a white paint, and is used to adulterate white-lead (Chemistry, § 83). Heavy spar also occurs in radiated, fibrous, granular, compact, and earthy modifications.

(2.) *Witherite*, or carbonate of baryta (BaO,CO_2), crystallises in regular rhombic prisms, and is principally found in this country. It is employed as the source of many of the other compounds of baryta; as, for instance, of chloride of barium, nitrate of baryta, &c.

10TH GROUP—STRONTIUM.

39. (1.) *Celestine*, or sulphate of strontia (SrO,SO_3), crystallises in the rhombic system (fig. 13), the rhombic prism being the prevailing form. Its cleavage is perfect; its fracture conchoidal or uneven; H $=$ 3 to 3·5; Sp. Gr. $=$ 3·8 to 3·96; it is transparent, double refractive, colourless or white, of vitreous lustre, and imparts a *crimson colour* to the flame of the blowpipe. It does not occur very frequently. The varieties of this mineral are:—*celestine-spar*, *radiated celestine*, and *fibrous celestine*, which has a blue tint, and is found at Jena; and *compact celestine*, which contains from 8 to 9 per cent. of carbonate of lime. These minerals are employed for the preparation of strontia-salts (Chemistry, § 84).

(2.) *Strontianite*, or carbonate of strontia (SrO,CO_2), is of less frequent occurrence than the preceding mineral; it crystallises in the same system.

11TH GROUP—MAGNESIUM.

40. This metal forms a rather larger group of minerals than the preceding metals. Amongst them may be mentioned *periclase*, which is nearly pure magnesia (MgO); hydrate of magnesia (MgO,HO); *boracite*, or phosphate of magnesia; and *hydroboracite*, containing, besides the latter substance, phosphate of lime and water. All these minerals occur but rarely, and in inconsiderable masses. *Sulphate of magnesia* (MgO,SO_3), is of more frequent occurrence; but, on account of its solubility, is only found as thin crusts or films of crystalline fibres in the clefts of rocks. In the Siberian steppes, however, whole districts are found covered with this and other magnesian salts. It is contained in large quantities in magnesian mineral waters, particularly in those of Epsom, Seidlitz, Eger, and Seidschütz.

Magnesite (carbonate of magnesia (MgO,CO_2)) occurs either crystallised, as *magnesite spar* (talc-spar), or as compact magnesite. The former crystallises in the hexagonal system, and is found in the form of obtuse rhombohedrons; H$=$4; Sp. Gr.$=$3. The magnesian limestone, consisting of lime, magnesia, and carbonic acid (CaO,CO_2+MgO,CO_2), is a mineral occurring in large masses. Its crystalline variety is called *bitter spar*, and sometimes *brown spar*. It occurs in obtuse rhombohedrons, nearly resembling fig. 20, which are easily cleavable, and of conchoidal fracture; H$=$3·5 to 4; Sp. Gr.$=$2·8 to 3. It is semi-transparent, has a vitreous lustre, and is white, or frequently coloured yellow or brown by the presence of iron or manganese. It is

principally found in clefts and cavities of the granular magnesio-calcite, which is called *Dolomite.* The white crystalline variety of Dolomite resembles marble, the coloured kinds are like common varieties of limestone; and as it occurs in large masses, it is employed for similar purposes.

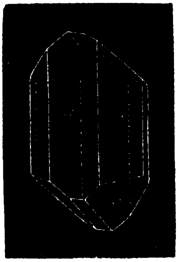
The combinations of magnesia with silicic acid, form a particular class of minerals, of which *Talc* is a prominent member. This mineral contains 62 per cent. of silicic acid, 30 per cent. of magnesia, and occurs principally as aggregates of imperfect crystals. It is smooth and unctuous to the touch, is very soft, and is white or faintly coloured. It is found in quantities as talcous slate. A variety of this mineral, called pot-stone, which may be cut and turned, is employed for the manufacture of various vessels. Besides the above, we shall mention, in connection with magnesia, the serpentine and augite minerals, which may be grouped into families.

1st Family—Serpentine.

41. This class comprises soft minerals, which may be cut with a knife, their hardness rarely exceeding 2·3. They do not occur in crystals, but are mostly opaque, difficultly fusible, and but slightly lustrous. They principally consist of magnesia and silicic acid, generally coloured by oxide of iron. To this family belongs the unctuous Steatite, which is employed for removing grease-spots, or as a soft polishing powder, and for the manufacture of a great variety of objects of art; soap-stone and the well-known meerschaum, which is used for the manufacture of tobacco-pipes, are also members of this family. *Serpentine,* which is called ophite, or snake-stone, on account of its green-spotted appearance, resembling the skin of a snake, forms compact masses of granular fracture, occurring as rocks. Its hardness is 3; it is employed for the manufacture of a number of objects, particularly columns, boxes, mixing-mortars for chemists and druggists, &c. There is, moreover, a large number of minerals resembling serpentine, which may be classed in this family.

2d Family—Augites.

42. These minerals possess a hardness between 4·5 and 7, and a specific gravity of 2·8 to 3·5. Their prevailing colours are dark green and black; they are fusible before the blowpipe. Their principal constituents are silica and magnesia, but some of them also contain considerable quantities of other oxides, such as sesquioxide of iron and alumina, which render it difficult to classify these minerals according to their chemical constituents. The augites occur in peculiar crystalline forms, and not unfrequently in considerable masses. They are also contained in many varieties of rocks, such as lava, basalt, &c. The most important members of this family are augite and hornblende, of which the various kinds are again distinguished by different names.



41.

Augite crystallises in prisms belonging to the fourth system; fig. 41 represents one of its usual forms; its different varieties occur principally in volcanic formations and their vicinities. The most important are—*diopside, diallage, bronzite, hypersthene,* and *kokolite.*

Hornblende belongs to the same crystalline system as the preceding mineral, with which it likewise exhibits similarity in its chemical composition and colour. *Asbestos*, *amianthos*, and *mountain cork*, must be considered as varieties of hornblende; they crystallise in exceedingly fine needles. The most pliable kinds of asbestos are mixed with flax and woven into stuffs and cloths, from which the flax is afterwards removed by simple ignition; and thus incombustible cloths are prepared, which may be worn in cases of danger from fire. The dead bodies of the rich were, in ancient times, enveloped in such garments, and then burned; by which means their ashes were preserved.

12th Group—ALUMINUM.

43. This group is exceedingly large and numerous, and must therefore be subdivided into families. Of these minerals there are only a few in which alumina, or sesquioxide of aluminum, in its uncombined state occurs, as the chief constituent. But the combinations of this base with silicic acid forms the principal constituent of many minerals, and the large quantity of silicic acid contained in these minerals, frequently renders it doubtful whether they should be classed among the silicious or among the aluminous group. This class contains a large number of minerals, which are important to the arts and to agriculture; it likewise includes the most precious jewels, next in value to the diamond.

1st Family—Corundums.

44. These minerals, consisting of pure alumina (Al_2O_3), occur in various forms. (1.) The crystallised variety is *sapphire*, which is found in various modifications of the hexagonal system. It is cleavable, and of conchoidal fracture; Sp. Gr. $=4$; H. $=9$; it is perfectly transparent, possesses a highly vitreous lustre, and beautiful blue colour; it is, however, also found of a red, green, yellow, and white colour, the red variety, which is called *ruby*, being very highly prized. The above properties render sapphire a very valuable gem: it occurs in small crystals in Germany, but the finest specimens are found in the East Indies, in diluvial soils and in the sand of rivers, which have their sources in such formations.

(2.) *Common corundum* is found in rough, scarcely translucent, dull, or dirty-coloured crystals, embedded in granitic rocks; being possessed of great hardness, it is reduced to powder, and employed for cutting and polishing other precious stones.

(3.) *Emery* occurs in compact or granular masses, which are found in Saxony, in Greece, and in other localities, embedded in mica-slate. It is but slightly lustrous, and has a bluish-gray colour. Its powder is frequently employed for cutting and polishing.

2d Family—Alums.

45. (1.) *Aluminite* ($Al_2O_3, SO_3 + 9HO$) is basic sulphate of alumina, and is found in small quantities as a white earthy mass. (2.) *Sulphate of alumina* ($Al_2O_3, 3SO_3 + 18HO$), termed also feather-alum, occurs in fibrous crystalline crusts, or in porous and compact masses. (3.) *Alum-stone*, consisting of alumina, potassa, and sulphuric acid, crystallises in the hexagonal system

as rhombohedrons, and is found chiefly in the vicinity of Rome, where it is employed for the preparation of Roman alum; which, as it contains no iron in chemical combination, was for a long time highly prized, until the progress of Chemistry made us acquainted with other methods of preparing alum free from iron. (4.) *Alum* ($KO,SO_3 + Al_2O_3, 3SO_3 + 24HO$), with which we have become acquainted in the section Chemistry, § 87, occurs likewise in Nature, crystallised in regular octohedrons. It is an interesting fact, that various minerals exist which have a composition corresponding to that of alum, in which the potassa is replaced by other bases, without the form of the crystal being in the least altered. Thus we are acquainted with:—

Potassa-alum	=	$KO,SO_3 + Al_2O_3,3SO_3 + 24HO$.
Soda-alum	=	$NaO,SO_3 + Al_2O_3,3SO_3 + 24HO$.
Ammonia-alum	=	$NH_4O,SO_3 + Al_2O_3,3SO_3 + 24HO$.
Manganese-alum	=	$MnO,SO_3 + Al_2O_3,3SO_3 + 24HO$.

a series of compounds, the formulæ of which present the greatest similarity. Such compounds as the above, containing different constituents, but crystallising in the same form, are termed *isomorphous*, that is, of similar form: we shall meet with several other examples of isomorphism as we proceed.

Phosphate of alumina is likewise found in the crystalline form, and is called *Wavellite.*

3D FAMILY—SPINELS.

46. These minerals are combinations of alumina and magnesia, and are represented by the formula MgO,Al_2O_3, in which the alumina occupies the place of an acid. They crystallise in regular octohedrons and in modifications of this form; they are distinguished by their hardness (H. = 8; Sp. Gr. = 3·8), lustre, and transparency, and are prized as valuable gems. Various kinds of spinel are distinguished by the colour: the scarlet variety, which is called *spinel ruby*, is the most highly prized; it occurs chiefly in the East Indies. Besides this variety, we are acquainted with blue, green, and black spinels.

4TH FAMILY—ZEOLITES.

47. The *Zeolites*, or *boiling stones*, so called on account of their containing water, with which they part with *intumescence*, when heated before the blowpipe, are mostly white, vitreous, and transparent; they possess a hardness of 3·5 to 6·5, and a specific gravity of from 2 to 3. Their principal constituents are silica and alumina. Although these minerals are interesting on account of their chemical composition, and particularly the variety and peculiarity of their crystalline forms, there is no member of the family that is of any importance with regard to frequency of occurrence or technical application. We must confine ourselves to mentioning a few of the best known zeolites, such as *analcime*, *harmotome*, or cross-stone, so called from the crystals crossing each other at right angles, *stilbite*, *chabasite*, *mesotype*; and those containing soda, namely, *natrolite*, *prehnite*, *Thomsonite*, &c.

5TH FAMILY—CLAYS.

48. By the term *clay* is understood a chemical combination of silica with

alumina (Al_2O_3,SiO_3), as has already been mentioned in Chemistry, § 87. The minerals of which clay is the principal constituent are either crystallised, possessing a hardness of about 7·5, transparent, and of vitreous lustre, or they are compact or earthy. All varieties of clay are difficultly fusible or perfectly infusible before the blowpipe. The more remarkable are:—

(1.) *Andalusite*, which occurs in regular rhombic prisms: H. = 7·5; Sp. Gr. = 3·1 to 3·2: it is infusible and generally flesh-coloured. (2.) *Chiastolite*, so called in consequence of a peculiar combination of each four crystals, the section of them exhibiting a mark similar to the Greek letter chi (X). (3.) *Disthène*, which crystallises in prisms, belonging to the 4th system; it acquries a bluish luminosity when gently heated; H. = 5 to 7; Sp. Gr. = 3·5 to 3·6.

The following are earthy clays, coloured red, yellow or brown by sesquioxide of iron or its hydrate: *Yellow ochre*, which is used as a colour. *Tripoli*, employed for polishing. *Bole*, or Lemnian earth, is a red clay, unctuous to the touch, and adheres to the tongue: it was formerly used in medicine, and is now employed as a colour, particularly for earthen utensils. *Terra de Sienna* is a brown clay, employed as a colour by artists and printers. *Lithomarge* occurs in fissures of various rocks.

The most valuable of all clays is the *porcelain earth*, or Kaolin, ($3Al_2O_3$, $4SiO_3$, + 6HO,) which, as will be shown hereafter, consists of disintegrated felspar, and forms large earthy masses, which are white, or only faintly tinted, and perfectly free from iron. This valuable material, which is used in the manufacture of porcelain, is found, though not frequently, in layers in granite and other rocks. Superior kinds are obtained from Cornwall, Schneeberg, Meissen in Saxony, Passau, Carlsbad, Limoges in France, and from many other places. That this earth is found in China and Japan is proved by the importation of the first porcelain from these empires, and also by the name *Kaolin* which has there been given to this mineral.

49. Common *clay* is of far more importance to the greater number of mankind than even porcelain earth. When somewhat similar to the latter it is called porcelain clay; or if it is white, pipe clay; Potters' clay, if coloured and of coarser quality. All clays are unctuous to the touch and adhere to the tongue, since they absorb and retain water with great avidity. They absorb fat and oil still more powerfully, and are hence employed for removing grease spots. Clay is also possessed of a peculiar odour, which arises from its property of absorbing ammonia from the atmosphere. Clay is infusible, and blocks of burnt clay are therefore employed, under the name of fire bricks, for building structures which are to sustain a high temperature, such as porcelain furnaces, blast furnaces, glass furnaces, &c. Earthy clay is employed for the manufacture of various kinds of pottery (Chemistry, § 88). By the admixture of lime clay loses its peculiar properties, particularly its infusibility; it then passes into marl and loam.

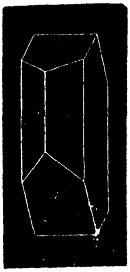
In concluding our description of this family, mention must be made of *agalmatolite*, a clay-stone, out of which the Chinese carve their idols, which, however, give us anything but a sublime conception of a deity.

6th Family—Felspars.

50. The name *spar* is very old, and was probably chosen to indicate a

cleavable crystallised mineral. The minerals of this class bear a great similarity in their composition to the zeolites, if the water contained in the latter be disregarded. Their hardness reaches to 7, their specific gravity to 3·3. They are mostly possessed of vitreous lustre, are generally coloured, and difficultly fusible before the blowpipe. The most remarkable are as follow:—

(1.) *Felspar* ($KO,SiO_3+Al_2O_3,3SiO_3$), which crystallises in prisms of a great variety of forms, belonging to the oblique rhombic system of crystallisation (fig. 14). Figs. 42 and 43 represent two of its usual crystals. It is perfectly cleavable, and has an uneven fracture; H. = 6; Sp. Gr. = 2·5; it is transparent, of vitreous lustre, white or flesh-coloured, and occasionally green. It occurs in aggregations of well-defined crystals, as also in large crystalline masses. It is found most frequently as a constituent of various kinds of rocks, particularly of granite, gneiss, and syenite, which renders it of particular importance. A bluish-green felspar, of peculiar internal nacreous lustre, is termed *adularia*, or *moonstone*. The amorphous compact felspar is called felspar rock or *felsite*. This forms likewise a principal constituent of several rocks.



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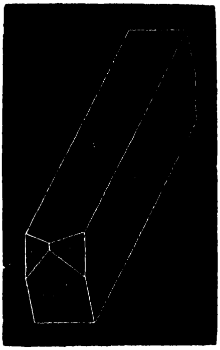


43.

(2.) *Albite* ($NaO,SiO_3+Al_2O_3,3SiO_3$) is felspar, containing soda instead of potassa. It is likewise an important constituent of many rocks. *Spodumene*, or oligoklase, is similar in composition. *Labradorite* is remarkable for its opaline reflections, of a blue, green, yellow, or red hue, somewhat resembling the colours observed on the breasts of pigeons and on many butterflies. Besides these varieties, we may mention *anorthite*, *leucite*, *nepheline*, *sodalite*, and *hauyne*.

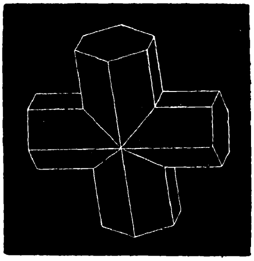
(3.) *Lazulite*, or *Lapis-lazuli*, is distinguished by its magnificent blue colour. It is found in Siberia, Thibet, and China, and is extensively employed in jewellery for ornamental works; when ground it is also used as a beautiful pigment, under the name of *ultramarine*. Since, however, chemists have become accurately acquainted with the constitution of this mineral, they have succeeded in preparing the above colour artificially. (Chemistry, § 89.)

The following minerals appear to be mixtures of silicic acid and felspar, which have become fused together, by a high temperature, to vitreous, slaggy, or spongy masses. *Obsidian* occurs, in black, blue, or greenish-black vitreous masses, and is employed for the manufacture of ornaments, such as boxes, buttons, &c. The South Americans employ this mineral for the manufacture of knives, weapons, &c. *Pumice-stone*, which is found in stream-like layers in the vicinity of volcanos, is very porous, fibrous, and vitreous, and is employed, as is well known, for cutting and polishing, particularly softer objects, since its hardness is only = 4·5. *Pearlstone* and *pitchstone* likewise belong to this family.

7th Family—Garnets.

51. This family embraces minerals of very remarkable crystalline forms; they do not, however, occur in large quantities, and are not applicable to the

arts, excepting to jewellery. Their hardness varies from 5 to 7·5; their Sp. Gr. from 2·6 to 4·3. They are mostly coloured and fusible before the blowpipe. Besides *Wernerite* and *Axinite*, the latter remarkable for the peculiar form of its crystals, fig. 17, *Tourmaline*, or schorl, is particularly worthy of mention. The latter crystallises in very complicated forms, which are derived from an obtuse rhombohedron of the hexagonal system. The usual forms are six-sided prisms, so much distorted as to resemble three-sided prisms, generally perfect only at one end. Its chemical composition cannot be well expressed by a formula; it may, however, be remarked that in addition to alumina and silicic acid, boracic acid is one of its principal constituents. It is worthy of mention that a crystal of tourmaline, when warmed, becomes negatively electric at one extremity and positively electric at the other. Tourmalines are found of all colours: the transparent green and brown crystals are employed in the investigation of certain phenomena of light.—It may be remarked of *Staurolite* that its crystals frequently occur in regularly-formed crosses (fig. 44).—The best known mineral of this group is *Garnet*, which crystallises in beautiful rhombic dodecahedrons (fig. 45), belonging to the regular system. It consists of silicate of alumina combined with a silicate of another metallic oxide, the latter, however, is not always the same, hence we have a series of garnets, analogous to the alums (§ 45) closely corresponding in their physical characters, and many of them occurring together in the same mass. Garnets are imperfectly cleavable, their fracture is conchoidal, H. = 6·5 to 7·5; Sp. Gr. = 3·5 to 4·2; they are mostly opaque, and occur of all colours. The beautiful deep red garnet (*Precious* garnet) is the most highly-prized variety, and is in great request for necklaces, earrings, &c. The greater number of garnets comes from the neighbourhood of Kulm in Bohemia. *Idocrase*, and *Epidote* are other remarkable minerals which belong to this family.



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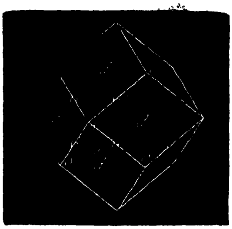


45.

8th Family—Mica.

52. The greater number of the minerals of this family is crystallised in small thin laminæ, of pearly lustre. These laminæ are very cleavable, pliable, and possessed of a low degree of hardness; hence the varieties of mica are smooth and unctuous to the touch. Their chemical composition cannot be expressed by a formula: silica and alumina are the prevailing constituents; many of the varieties contain, however, a considerable quantity of magnesia. Mica is often colourless, but sometimes it is coloured, particularly green and black.

Common or *Potassa Mica* is very largely distributed, particularly in various rocks—for instance, in granite, gneiss, and mica-slate, in which it is observable as lustrous laminæ. It occurs in Siberia in very large plates, which are employed instead of glass for windows. Of the various kinds of mica we

may mention *chlorite*, remarkable for its fine green colour, which it imparts also to those kinds of rocks of which it is a constituent, for instance, to *chlorite slate*. *Lepidolite*, or Rose Mica, which contains lithia, belongs to this family.

9th Family—Gems.

53. This class embraces all minerals that possess properties which adapt them to the purposes of the jeweller—hardness, beauty of colour, brilliancy of lustre, rarity, &c. We have already spoken of the diamond, the ruby, and the sapphire. The other minerals of this family have a Hardness of from 7·5 to 8·5, and a Sp. Gr. of from 2·8 to 4·6: they are transparent, difficultly fusible or infusible, and are generally possessed of beautiful colours. Among them may be mentioned *topaz*, which is generally of a fine yellow colour; *pale green chrysoberyl*; *emerald*, remarkable for its beautiful green colour; and *zircon*, of which the hyacinth-coloured variety is most prized, and has received the name of *hyacinth*. The crystals of the two first-named minerals belong to the rhombic system, and those of the emerald to the hexagonal system. Fig. 35 is the usual natural form of the emerald.

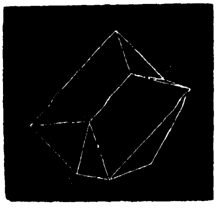
SECOND ORDER—HEAVY METALS.

13th Group—IRON.

54. Iron forms a very important group of minerals, remarkable both for their great variety of form and for the large masses in which they occur. Their Sp. Gr. reaches to 8·0; the greater number is opaque and coloured, and possesses the hardness of quartz. They are attracted by the magnet, and yield, with borax, a dark red glass in the outer blowpipe flame, and a bottle-green glass in the inner flame. Regarding their application to the extraction of iron, sufficient details have been given in the section Chemistry (§ 90). The most important minerals of this group are:—

(1.) *Native Iron*, occurs only rarely in layers or veins of inconsiderable thickness, or in grains and laminæ. The most remarkable variety is the *meteoric iron*, consisting of masses of native iron which have fallen from the atmosphere, and which weigh from 171 to 3,000, or even 14,000 pounds. Mention may be made here of the *meteoric stones* which contain, with few exceptions, native iron, besides other earthy constituents, such as augite, hornblende, olivine, &c.

(2.) *Magnetic Iron* ($FeO + Fe_2O_3$), crystallises in regular octohedrons (fig. 1), and often in macles (fig. 46). It is remarkable for its magnetic properties: it also occurs in compact masses of considerable magnitude, forming entire mountain strata. It is one of the most highly-prized ores of iron, being used chiefly for the manufacture of steel.



46.

(3.) *Red Iron Ore, Sesquioxide of Iron* (Fe_2O_3), or *Red Hæmatite*, crystallises in the hexagonal system as a rhombohedron and its derivatives. It is possessed of bright metallic lustre and red streak, and likewise yields a red powder. It occurs in various forms, as crystallised *iron glance*, micaceous iron,

fibrous hæmatite (bloodstone), and also as compact, scaly, and earthy red ironstone, the latter of which is also called *red iron ochre.* If it contains an admixture of clay, it is called in Germany *clay ironstone;* but this is not the important ore that bears that name in Scotland. These minerals are important as iron ores, and are also employed in smaller quantities as polishing materials and as red paint.

(4.) *Brown Iron Ore* (Hydrated Sesquioxide of Iron, Fe_2O_3+2HO) does not occur in a distinctly crystalline form. The fibrous brown ironstone, however, consists of fine capillary crystals, radiating from a centre, and forming spherical and botryoidal masses. Besides this variety there is the compact and earthy brown ironstone, which, by containing clay, forms the transition member to the brown and yellow clay ironstones, of which we may mention the yellow ochre and umber, both used as colours. *Pea iron ore*, and *Morass ore*, the ironstone which is deposited in morasses, belong to this class; the latter is less valuable for the extraction of iron than the foregoing.

55. Iron occurs combined with sulphur in various proportions, and generally as fine crystallised minerals, of a brass-like lustre, which are called *pyrites.* Of these we may mention:—

(5.) *Magnetic Iron Pyrites* (Fe_2S_3+5FeS), which crystallises in six-sided prisms and is attracted by the magnet.

(6.) *Iron Pyrites* (FeS_2), crystallises in the regular system, particularly as a pentagonal dodecahedron (fig. 10) and its modifications; its Hardness is $=$ 6 to 6·5, hence it produces sparks when struck with steel. It occurs very plentifully, and sometimes in very fine laminæ and grains, in coal, for instance, and yields protosulphate of iron when oxidised by exposure to the air, particularly in the presence of water (Chemistry, § 93). This salt occurs in the mineral kingdom under the name of *Green Vitriol.*

The remaining ferruginous minerals, of which there is still a large number, are most of them of little importance with regard to the quantity in which they occur, and likewise in their applications: we will therefore only mention the most important:—*Vivianite*, or blue iron ore (phosphate of sesquioxide of iron); *green ironstone*, which is the same chemical compound, containing water of hydration, and then the series of combinations of arsenic with iron, called *arsenical pyrites*, which possesses a white metallic lustre. Of the latter may be mentioned *arsenical iron*, *scorodite*, *pharmacosiderite*, the arsenical pyrites containing sulphur, which is also termed *mispickel.*

Carbonate of Iron (FeO,CO_2) occurs in larger quantities; when crystallised it is called *Spathic ironstone.* It forms very obtuse rhombohedrons. This ore is admirably suited for the production of steel. It is also found in the fibrous form, and is then called *sphærosiderite.* The *Clay ironstone* of the Scotch metallurgists consists of carbonate of iron, in combination with variable quantities of carbonate of lime, clay, &c. It is a mineral of great importance.

The *green earth*, which is employed as a colour under the name of *Veronese green*, is silicate of sesquioxide of iron with lime and a little magnesia. *Chrome iron* ($FeO+Cr_2O_3$), which consists of sesquioxide of chromium and protoxide of iron, occurs generally in compact, granular, crystalline masses, and is important, as being the mineral from which the compounds of chromium are prepared (Chemistry, § 103).

14th Group—MANGANESE.

56. This metal generally occurs as oxide; in addition to its being the principal constituent of several minerals, it is found in many others in smaller quantities as their colouring matter. The fused minerals are generally coloured violet, whilst the massive minerals are usually brown or black. The most important varieties are:—

Pyrolusite (Binoxide of Manganese, MnO_2), which occurs crystallised in regular rhombic prisms, but is most generally found in masses consisting of aggregates of acicular crystals. Its colour and streak are black; its Hardness is $= 2$ to $2{\cdot}5$; its Sp. Gr. $= 4{\cdot}9$. The valuable application of this mineral to the preparation of chlorine has already been referred to (Chemistry, § 35 and 94).

Hausmannite (Proto-sesquioxide of Manganese, $MnO + Mn_2O_3$), which crystallises in quadratic octohedrons, is brownish-black or black, produces a brownish-red streak, and occurs generally associated with pyrolusite.

Braunite, or Protoxide of Manganese, has the same crystalline form as hausmannite; its colour and streak are both dark brownish-black. The value of pyrolusite is naturally much decreased by an admixture of these two minerals; hence, in purchasing this mineral for practical purposes in the arts, particular attention must be paid to the colour and streak.

Manganite (Hydrated Sesquioxide of Manganese) is of less importance in the arts. Sulphate of Manganese, or Prismatic *Manganese Blende*, Silicate of Manganese, Carbonate of Manganese, or Red Manganese, and many other minerals of this family, have not received any application in the arts.

15th Group—COBALT.

57. The minerals of this scarce metal are mostly sulphuretted or arsenical compounds. They are opaque and coloured, and yield a blue glass with borax before the blowpipe. The most important are: Sulphide of Cobalt (Cobalt Pyrites, Co_2S_3), possessing a white colour, a metallic lustre, and crystallising in regular octohedrons; *Arsenical Cobalt* (Speiscobalt, $CoAs_2$), occurring in cubes, of a white colour, and metallic lustre, in the Erzgebirge in Saxony; *Arsenical Cobalt Pyrites* ($CoAs_3$); *Cobalt Bloom*, or hydrated arseniate of cobalt; *Cobaltine*, or white cobalt ($CoS_2, CoAs_2$), crystallising as pentagonal dodecahedrons, with metallic lustre, and pinkish colour; and, finally, *Earthy Cobalt*, occurring as compact earthy masses, of a black colour. The latter consists of a mixture of oxide of cobalt, with a considerable quantity of oxides of manganese, copper, and iron. All these minerals are employed for the extraction of cobalt, and especially for the preparation of the cobalt glass called Smalts (Chemistry, § 95).

16th Group—NICKEL.

58. The minerals of this group are not of more frequent occurrence than those of the preceding group, and they usually occur under similar circumstances. They also generally contain a small admixture of cobalt, sufficient to yield a blue glass with borax. The most important are:—

Sulphide of Nickel (NiS) which occurs in capillary or acicular crystals; *Red Arsenical Nickel* (Kupfer nickel NiAs), occurring but rarely crystallised,

generally compact, dentritic, or botryoidal, and possessing a copper-red metallic lustre; *White Arsenical Nickel* ($NiAs_2$), of tin-white metallic lustre; *Nickel Ochre*, or arseniate of Nickel; *Nickel Glance*, or white nickel ore (NiS_2+NiAs_2) of gray metallic lustre. Nickel also occurs in combination with several metals; for instance, it is associated with antimony as antimonial nickel (NiSb), and as antimonial nickel pyrites (NiS_2+NiSb_2), with bismuth as *bismuth nickel pyrites*, and with iron as *nickel iron pyrites.*

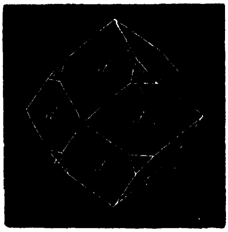
All these minerals are but impure chemical compounds, containing always more or less iron, copper, cobalt, lead, &c. Nickel ores are employed for the extraction of nickel, which is extensively used in the manufacture of German silver. They are found in the Erzgebirge, and also at Riechelsdorf in Hesse.

17th Group—COPPER.

59. This metal forms a large group of minerals, as it occurs not only in great masses, but also in the most manifold combinations. Only a comparatively small number, however, are employed for the extraction of copper. The Hardness of the minerals of this group ranges from 2 to 4, and their Sp. Gr. to 6; they yield metallic copper before the blowpipe. The following are the most important:—

(1.) *Native Copper*, which seldom exhibits a crystalline form, but generally occurs in peculiar arborescent or moss-like formations. It is frequently found in considerable masses, and is worked for copper.

Red Oxide of Copper (suboxide of copper, Cu_2O) crystallises very beautifully in distinct crystals of many forms of the octohedral system, namely, the cube (fig. 3), the octohedron (fig. 1), the rhombic dodecahedron (fig. 7), the triakisoctohedron (fig. 49), and in many combinations of these forms, as in fig. 47, where the dodecahedron predominates over the octohedron, and fig. 48, where the octohedron predominates over the dodecahedron. Fig 2. also presents one of the numerous varieties of this mineral.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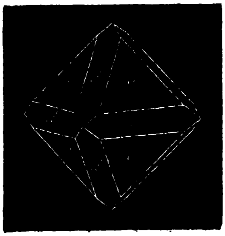
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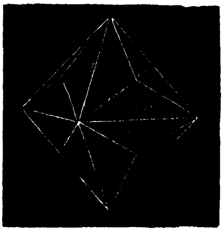
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This mineral has a beautiful red colour, but it is generally coated with green. It yields very fine copper. *Black oxide of copper* is found only in very small quantities.

Vitreous Copper (Sulphide of Copper, CuS) occurs in tabular rhombic prisms of blackish lead-gray metallic lustre, and is worked for copper.

The soluble salts of copper produced in small quantities by the decomposition of other copper ores, particularly of sulphide of copper, are of little

importance. They are found principally in the neighbourhood of volcanos, from the fissures of which vapours issue containing hydrochloric and sulphurous acids. Of these salts may be mentioned: sulphate of copper (blue vitriol CuO,SO_3), various phosphates and arseniates of copper, chloride of copper, &c.

The two following may be classed among the most beautiful productions of the mineral kingdom:—

(1.) *Malachite*, or Carbonate of Copper (CuO,CO_2+HO), which crystallises in irregular rhombic prisms, generally uniting into fibrous radiating groups, possesses a fine emerald-green colour, and silky lustre. It also occurs in compact and earthy masses, and is employed for ornamental purposes, and as a pigment; where it occurs in larger quantities, as in Australia, it is worked for copper.

(2.) *Blue Carbonate of Copper* (azure copper ore) is carbonate of copper combined with hydrated oxide of copper, and occurs either in short prismatic or tabular crystals, or in irregular, compact, and earthy masses. This mineral is remarkable for its beautiful blue colour, and is hence employed as a pigment. The *Silicate of Copper* ($3CuO,2SiO_3$), which is termed Chrysocolla, has a fine green colour.

Another series is formed by those minerals in which copper exists in combination with other metals, and in which sulphur is usually a constituent. Of these we may mention Bismuthic Sulphide of Copper (needle ore), Antimonial Sulphide of Copper (Bournonite), Tin Pyrites and *Purple Copper* (Buntkupfererz). The last is a mixture of sulphides of copper and iron. It crystallises in regular octohedrons, and in the forms represented by figs. 3, 52, 2, 4, and 5. It has the lustre of brass, but generally presents the most beautiful variegations of blue and red. *Copper Pyrites* ($CuS+FeS$) crystallises in quadratic octohedrons, and bears much similarity to the last-mentioned mineral. It is the most abundant of all the ores of copper, and, like the purple copper, is frequently smelted.

In concluding our enumeration of copper minerals, we may mention *Fahl Ore* (gray copper ore), which crystallises in the regular tetrahedral system, but usually occurs in very complicated hemihedral combinations, of which the modified tetrahedron (fig. 50) is one of the simplest. It possesses a gray metallic lustre: its principal constituents are copper, antimony, sulphur, and arsenic, with variable quantities of iron, zinc, and silver. Hence several varieties of this mineral are found. They are all worked for copper, and the richer specimens also for silver.

50.

18TH GROUP—BISMUTH.

60. The minerals of this metal are of secondary importance with regard to their distribution and number. Some of the most important are:—*Native Bismuth*, which occurs in regular octohedrons, possessing a reddish silvery lustre; H. $=2$ to $2·5$; and Sp. Gr. $=9·7$; *Bismuth Ochre*, or sesquioxide of bismuth (Bi_2O_3), occurs in company with the former, particularly in the mountains of Saxony; *Bismuthine*, or sesquisulphide of bismuth (Bi_2S_3), crystal-

lises in rhombic prisms, of a lead-gray metallic lustre. *Bismuth Blende* consists of silicate of bismuth, and possesses the highest specific gravity of all the ores of this group (5·9). Bismuth has met with but few applications. It is a usual ingredient of fusible alloys.

19TH GROUP—LEAD.

61. This metal rarely occurs in the native state, but generally in combination either with oxygen or sulphur in minerals of low degrees of hardness, but of high specific gravity (4·6 to 8). These combinations when heated before the blowpipe yield with great facility metallic lead and the yellow oxide of the metal. Many of the minerals of this group occur only in inconsiderable quantities, such as *native lead*, *minium*, or lead ochre, *binoxide of lead*, *chloride of lead*, and many others.

On the other hand, the *Sulphide of Lead*, or *Galena* (PbS), is the most abundant mineral of this group, and is that which is principally worked for lead. With the applications of this metal we have already become acquainted. Galena crystallises in the regular system, particularly in cubes, octohedrons, and triakisoctohedrons, and the various modifications of these forms; it likewise occurs in compact masses, which are more or less finely granulated or dense. This mineral is always distinguished by its high specific gravity (reaching to 7·6), its lead-gray and brilliant metallic lustre, and easy cubical cleavage.

Galena frequently contains silver, in sufficient quantity to render it worth extracting (Chem. § 107). It is likewise occasionally found to contain gold, antimony, iron, and arsenic.

An extensive series of minerals is formed by the combination of lead, antimony, and sulphur, in various proportions. Of these we may mention *Zinkenite*, *Jamesonite*, Sulphide of Antimony and Lead, &c. most of which are named after the discoverers.

Of the Salts of Lead we may mention sulphate of lead (PbO,SO_3), which crystallises in rhombic octohedrons, and is distinguished by its brilliant lustre and white colour; *White Lead ore*, or Carbonate of lead, which crystallises in regular rhombic prisms, and is remarkable for its adamantine lustre and double refractive power. Passing over the combinations of lead with the rarer elements, we merely mention Chromate of Lead (Chem. § 103), which occurs in a beautiful crystalline form in the Uralian mountains.

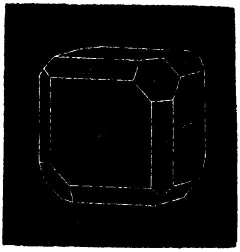
20TH GROUP—TIN.

62. Tin does not occur native, but generally as *Tinstone*, which is the binoxide of this metal (SnO_2). This mineral crystallises in quadratic octohedrons, the modifications of which are frequently found in twin crystals. They vary from semi-transparency to opacity, possess a high lustre, are sometimes white, but more generally coloured, and sometimes even black. *Fibrous Tin Ore*, which likewise consists of binoxide of tin, occurs in much larger masses, having a fine fibrous structure. Cornwall and the East Indies are particularly rich in tin ores, from which the metal may easily be extracted by fusion with charcoal.

21ST GROUP—ZINC.

63. Oxide of Zinc is occasionally found in the form of crystalline masses

of a red colour, and is called *Red Oxide of Zinc.* A much more plentiful mineral of this group is *Zinc Blende*, which consists of zinc and sulphur (ZnS). It crystallises in the regular system, its most usual forms being the rhombic dodecahedron (fig. 7), the cube (fig. 3), the octohedron (fig. 1), the tetrahedrons (figs. 8 and 50), the macle (fig. 46), and the complex form represented by fig. 45, in which the cube is modified by the planes of the rhombic dodecahedron (fig. 7), and the tetrahedron (fig. 9). The fracture of zinc blende is conchoidal; H. = 3·5 to 4; Sp. Gr. = 4·1; it possesses an adamantine lustre. Its colour is green, yellow, red, brown, or black. It occurs laminated, fibrous, radiated, in compact masses, and is worked for zinc.



51.

Sulphate of Zinc (ZnO,SO_3) is also found, though only in small quantities, but the Carbonate of Zinc, or *zinc spar*, occurs more frequently. The latter crystallises in the hexagonal system, in the form of rhombohedrons; it possesses a vitreous lustre, and is generally white or only slightly coloured. It is employed chiefly in the manufacture of brass. *Calamine* (silicious oxide of zinc) is the most common mineral of this group, and is employed for the same purpose; it consists of oxide of zinc and silicic acid, and crystallises in rhombic prisms. This mineral is possessed of a remarkable lustre, and is either white or slightly yellow. When heated, the crystals of this mineral exhibit polaric electricity in a remarkable degree, and likewise acquire luminous properties by friction.

22D GROUP—CHROMIUM.

64. It is highly remarkable that this metal, of which the chemist prepares a great number of the most beautifully-coloured compounds, should only occur in a comparatively small number of natural combinations. This may in some measure explain the circumstance of chromium having been discovered so recently as 1797. In addition to Chromate of Lead (§ 61), and Chrome Iron ore (§ 55), already referred to, we have only to mention *Chrome Ochre* (sesquioxide of chromium, Cr_2O_3), which occurs but rarely and in small quantities. There are, however, several other minerals which contain a small quantity of chromium.

23D GROUP—ANTIMONY.

65. The minerals of the antimony group are possessed of a Hardness reaching as high as 6·6; and a Sp. Gr. = 4. Before the blowpipe they yield white vapours, which form a bluish-white incrustation upon charcoal. The rarer minerals of this group are: *Native Antimony*, *White Antimony* (teroxide of antimony, SbO_3), and *Antimonial Ochre* ($SbO_4 + HO$).

The *Tersulphide of Antimony* (SbS_3) occurs more frequently, and is a combination of antimony with sulphur, which crystallises in the rhombic octahedral system. Its crystals are mostly long, columnar, and acicular, aggregated together, and generally possess a lead-gray metallic lustre. This mineral is employed in the preparation of metallic antimony, and is also used in medicine.

Red Antimony is a compound of oxide with sulphide of antimony, and is distinguished by its cherry-red colour, and the adamantine lustre of its spear-shaped crystals; it is one of the rarer ores of this metal.

24TH GROUP—ARSENIC.

66. This poisonous metal occurs in many metallic compounds, with the greater number of which we have already become acquainted, for example, Arsenical Iron, Arsenical Cobalt, Arsenical Nickel, &c. The minerals of the arsenic group yield white fumes before the blowpipe, which have a powerful odour of garlic. The white fumes consist of the highly poisonous arsenious acid. The odour is produced by vapourised metallic arsenic. The most remarkable minerals of this group are:—

Native Arsenic, which is not of unfrequent occurrence; it is found less frequently crystallised than in the form of roundish, heavy, and compact fragments. It possesses a tin-white or gray-metallic lustre, but soon becomes blackish by exposure to the air; H. = 3·5; Sp. Gr. = 5·7. It frequently occurs mixed with antimony and silver.

Arsenious Acid (AsO_3) may be considered as a product of the preceding mineral, occurring only in inconsiderable quantities, and generally in irregular forms, having an adamantine lustre and whitish colour.

Realgar (AsS_2) is the lower sulphide of arsenic; it crystallises in irregular rhombic prisms, but also occurs in compact masses. It has a fatty lustre, a bright red colour, and gives a yellow streak. It is employed as a colour, and as a constituent of the white fire in pyrotechny. *Orpiment* (AsS_3) is the higher sulphide of arsenic, which is rarely found in the crystallised state, but generally in roundish masses; its lustre is fatty, and its colour bright lemon-yellow; it is hence employed as a pigment (Chem. § 46).

25TH GROUP—MERCURY.

67. Although liquid, this metal occurs native, and is found in the form of larger or smaller globules in the cavities and fissures of clay slate, and carboniferous sandstone, as for instance at Moshellandsberg in Rhenish Bavaria. The greater quantity of mercury, however, is obtained from *Natural Cinnabar* (HgS), which occurs crystalline and in botryoidal and compact masses, H. = 2·5; Sp.Gr. = 8. Cinnabar is opaque, and of adamantine lustre; its possesses a carmine colour, and gives a bright scarlet streak. It becomes black on being heated, but resumes its red colour on cooling. The principal localities in which it is found are Rhenish Bavaria, Almaden in Spain, Idria in Carniola, Mexico, China, and California.

Native Chloride of Mercury ($HgCl$) is a mineral of less frequent occurrence. A mixture of cinnabar, carbon, and earthy matter, occurring in Idria, is called *liver ore*, or *hepatic cinnabar*.

26TH GROUP—SILVER.

68. This is one of the more frequent metals, occurring native, as well as in a great variety of minerals, alloyed with other metals, or combined with arsenic and sulphur. Silver ores yield metallic silver when heated before the blowpipe alone, or with carbonate of soda.

Native Silver occurs either in small crystals, of the cubical system, in crys-

talline groups, or in a great variety of curious forms, sometimes arborescent or like moss, as also in laminæ, irregular masses, and grains. H. = 2·5 to 3; Sp. Gr. = 10·3. It possesses the common properties of silver, but is generally tarnished of a yellowish or brown colour. It is found in most countries; in Germany it occurs with other silver ores, particularly in the Saxon Erzgebirge.

The most important ores that are worked for silver are the following:—

Sulphide of Silver, or Vitreous Silver (AgS), crystallises in the cubical system, but occurs more frequently in irregular forms, of a gray or black colour, and metallic lustre. It is also found as an earthy mineral, under the name of *Black Sulphide of Silver.*

Antimonial Silver, containing from 70 to 80 per cent of silver, occurs in modifications of right rhombic prisms. It has a silvery or yellow metallic lustre, but is more generally coated with a black tarnish.

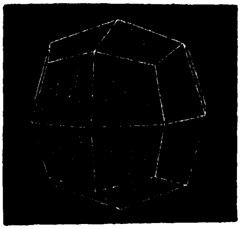
Brittle Sulphide of Silver is a combination of the sulphides of silver and antimony, containing about 70 per cent of silver. It occurs in right rhombic prisms and irregular masses, possessing a metallic lustre and an iron-black colour. The most important silver ore, however, is *Ruby Silver*, which consists of silver, antimony, sulphur, and arsenic. It crystallises in modifications of the rhombohedron, has an adamantine lustre, a colour ranging from iron-black to crimson, and produces a beautiful crimson streak. H. = 2·5 to 3; Sp. Gr. = 5·5 to 5·8. It contains from 58 to 64 per cent of silver.

Sulphide of Silver and Copper contains about 52 per cent of silver, and occurs in blackish-gray crystals of the rhombic system, possessing metallic lustre.

Besides these we may mention the names of several minerals, which occur more rarely, and are therefore of secondary importance. *Chloride of silver* (horn-silver), bromide of silver, carbonate of silver, bismuthic silver, sternbergite, polybasite, and many others.

27TH GROUP—GOLD.

69. It is indeed highly remarkable, that the more precious the metals the more they appear to be isolated and separated from the other mineral substances of common occurrence. Thus gold is generally found native, either crystallised in the several modifications of the regular system, as represented by figures 1 to 9, and 52, 53, and 54, or in the most varied shapes, such as



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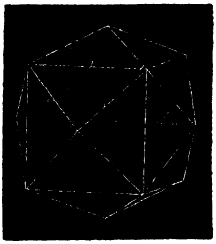

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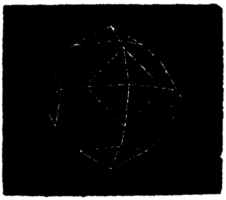


54.

dentritic, capillary, arborescent, foliaceous, &c. It is likewise found in irregular masses and grains, and finally as sand and dust; it exists in the two latter forms disseminated in various kinds of rocks, such as granite, &c.

and owing to their disintegration, it finds its way into the sand of rivers, and the rubble-stones of alluvial soils.

As the specific gravity of gold in this state is as high as 19·4, the smallest grains may be separated from sand by washing, the gold being immediately deposited.

Silver is the metal which occurs most frequently associated with gold; natural alloys of these two metals are found, containing from 0·16 to 38·7 per cent of silver, which causes considerable variations both of colour and density. In addition to this alloy, we may mention *sylvanite* (graphic tellurium), which contains, besides gold and silver, one of the rarer metals, viz. tellurium.

Europe in general is poor in gold; the only rich gold mines are at Kremnitz, in Hungary. The East-Indies, South America, California, Australia, and the Ural mountains, are rich in this metal, pieces of gold of considerable size having been found in these localities. In the year 1842 a mass weighing 86 pounds was found in the gold-sand district of Alexandrowsk, near Miask. Pieces of 23 to 24 pounds' weight are not unfrequently met with. The most important rivers of Germany, in which gold is found, are the Rhine, the Danube, the Isar, and the Inn.

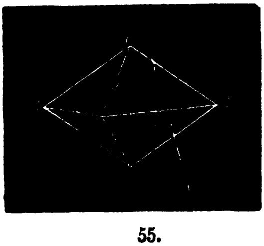
28th Group—PLATINUM.

70. Platinum is likewise found only in the native state; it generally occurs in nodular pieces and grains, and but rarely in the crystalline form, as cubes. It is frequently alloyed with other metals, more particularly with iron, of which as much as from 5 to 11 per cent is sometimes present. The specific gravity of native platinum is from 17 to 18; its colour is steel-gray. It was first discovered in America, where it received the name of platina, signifying *similar to silver* (plata being the name of silver). It was afterwards found in quantities in the Ural mountains, where it occurs in alluvial formations, but more frequently in the rubble-stones of serpentine rocks. Masses weighing from 10 to 20 pounds have been found in these localities.

THIRD CLASS.—MINERALS OF ORGANIC COMPOUNDS.

29th Group—SALTS.

71. As belonging to this small group of minerals we may mention *Humboldtite*, consisting of oxalate of protoxide of iron; and *honeystone* or mellite, a combination of alumina with an acid, consisting of carbon and oxygen (of the formula C_3O_4), which has been named after the mineral mellitic acid. This mineral has received its name from its peculiar honey-yellow colour; it crystallises in transparent, quadratic octohedrons, similar to figures 55 and 56. Both minerals are of rare occurrence, and of no practical importance.



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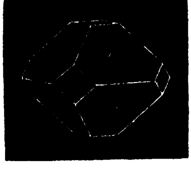


56.

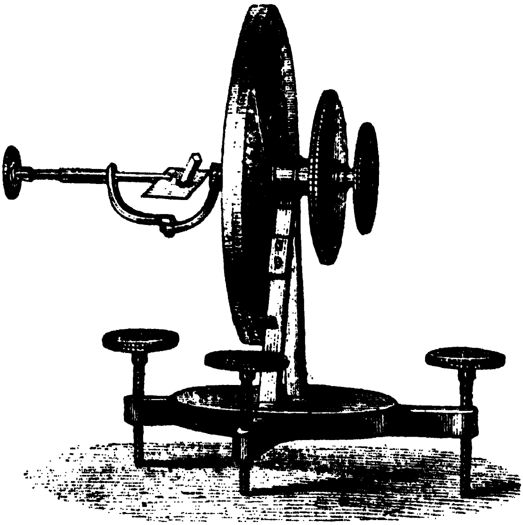
30TH GROUP—EARTHY RESINS. (BITUMENS.)

72. This group comprises solid and liquid organic compounds, the most important properties of which have been described in the chemical section of this work, among the resins and volatile oils (§ 171). They consist of more or less metamorphosed products of the vegetable remains of a former period, as we have already stated in our chapter on the dry distillation of vegetable matters (Chem. § 170). They occur only in the latest formations of the earth's crust. The most remarkable are:—

Amber, a fossil resin, occurring principally in brown-coal formations, and generally in the brown-coal itself. The greater quantity is found in detached pieces on the sea-shore, where it has been washed by the waves, or in the sand and loam, more or less distant from the beach. Amber is fished and dug for more particularly on the east coast of Prussia, from Dantzic to Memel. Pieces of amber are found with fragments of wood and bark adhering; other specimens contain insects, pine-needles and cones enclosed, which leaves no doubt that it originates from a fossilised or an extinct species of pine. Regarding its other properties and applications, see Chemistry, § 143.

Other rarer members of this group are, fossil copal, retinite, mountain or earth wax, elastic bitumen, mountain tallow or Scheererite, idrialite, &c.

Mineral or *Persian Naphtha*, which occurs either limpid or semi-fluid, is described in Chemistry, § 171, where we have also given a description of *Asphaltum* and *Bitumen*.



[Wollaston's Goniometer, an instrument for measuring the angles of crystals.]

(Physics, § 121) will rise one degree. This remarkable increase in the temperature of the earth towards its centre, amounting to one degree for every 120 feet, has been proved to be the same at every point of the globe, and at all depths.

Now, if the increase of heat progresses in the same ratio towards the deeper and unknown parts, we are entitled to assume that, at the depth of 36 miles it would attain to 1,800° C. (3,272° F.), a temperature at which iron would melt; at 54 miles a heat of 2,700° C. (4·892° F.) would prevail, in which all known substances would become molten liquids. Hence it seems but natural to conclude that the interior of the earth is one burning mass of liquid fire surrounded by a crust, which has cooled down gradually and consequently become hardened. We shall see, in the following pages, that there are many other reasons for such a conclusion; we may merely allude here to thermal springs, the waters of which are the hotter the deeper their source may be.

77. A diligent and attentive investigation of the crust of the earth was first undertaken in Germany, where Werner, Professor of Mining at Freiberg, gave the first impulse to the study. We owe, however, the abovementioned important discovery of the uniform distribution of the various kinds of rock, to the illustrious traveller Alexander v. Humboldt, and to the indefatigable Leopold v. Buch.

78. In order correctly to distinguish any kind of rock, we must of course first consider it mineralogically, *i. e.* investigate its chemical constituents, its hardness, its density, &c. Then we have to regard the form of the rock; for although we have no crystals to contemplate in this case, the rocks considered in their entire mass, present, each in its kind, a very peculiar form. Next to this, the peculiarity of their arrangement and stratification is of great importance; and finally, the numerous animal and vegetable fossils enclosed in many of the rocks, contribute most essentially to characterise and distinguish them. Thus we may arrange the subject of our study in the following divisions:—1. *Mineralogical description of rocks.* 2. *Configuration of rocks.* 3. *Stratification of rocks.* 4. *Petrifactions.* These four branches constitute DESCRIPTIVE GEOLOGY. After having elucidated these, we may proceed to the consideration of the structure of the earth's crust, the formation of the various chains of mountains, and their connection with one another, which constitute what may be termed SYSTEMATIC GEOLOGY.

DESCRIPTIVE GEOLOGY.

A. MINERALOGICAL DESCRIPTION OF ROCKS.

79. In endeavouring to distinguish the different kinds of rock, we meet with the same difficulty as in the study of minerals (§ 24). Here, likewise, ocular examination, observing the deportment of the rock under the hammer, attentive consideration of the mountains, vales, water-courses, quarries, mines, &c. are absolutely necessary in order to form a correct conception of the entire subject.

The following description of rocks may, therefore, more correctly be called a mere outline or sketch of the most important members. If we have once succeeded in acquiring a clear conception of these individual rocks, and have well understood the method of studying rocks in general, the study of any

other kinds will present no difficulty to the student. As in mineralogy so in geology, collections are highly to be recommended to the student; and as rocks generally occur in great masses it is much easier to make a collection of these than one of minerals.

80. The minerals, which form a considerable part of the earth's crust, are termed, in general, *rocks*. These rocks, according to their structure, are of two kinds: either they consist of minute particles (for instance, of crystals, grains, laminæ, &c.) of one and the same mineral, or of two, three, or four different minerals mixed with each other. There are accordingly two principal classes of rocks, viz. *simple* and *mixed* rocks. Thus, for instance, *marble*, consisting of nothing but grains of carbonate of lime, is a simple rock. *Granite*, on the contrary, in which we find quartz, mica, and felspar, is a mixed rock.

81. Many terms that have become familiar to us in the description of minerals are of course also employed in that of rocks, as, for instance, granular, spathous, fibrous, foliated, compact, earthy, &c. There are, however, several peculiarities observable in the structure of mixed rocks, arising from the manner in which the mixture is formed. The component parts are either crystallised together or united by a non-crystalline mass, in the same manner, for instance, as mortar binds the stones of a wall. In many the cohesion is very great, in others but slight, and these latter are called *loose* rocks, as, for instance, rubble-stones, gravel, marl, &c. The mixture is either *distinct* and discernible by the naked eye, or it is *indistinct*, and can be detected only by the help of glasses or by chemical means. A rock is called *slaty* when it splits easily in one direction. which is commonly the case whenever one of the component parts, or all of them, have the form of small laminæ arranged in parallel layers. The *porphyritic* rocks are very peculiar, they consist of a homogeneous mass interspersed with crystals of any mineral, from which it derives its spotted appearance. If a rock contains vesicular cavities filled partly or entirely with another mineral, similar in shape to an almond, it is called *amygdaloidal;* if, however, these cavities occur frequently in it, and are empty, the rock is called *slaggy*. *Geodes*, or *drusic cavities*, are intermediate spaces in the masses of rocks, lined with beautiful crystals. Finally we must mention *accidental* admixtures, such as isolated crystals of any mineral, which, however, are present in so inconsiderable a number as to have little influence on the specific character of the rock. Thus, for instance, in granite single garnets are sometimes found, the presence of which, however, does not at all affect the character of the granite.

Classification of Rocks.

82. Rocks may be classified in various ways; for instance, into granular, spathous, foliated rocks, &c.: it is, however, highly essential that such an arrangement does not separate those rocks that are chemically allied to each other.

The character of a rock is generally more difficult to define than that of a mineral, particularly as one species frequently makes a transition into another; thus, for example, compact limestone passes into granular limestone, and granite into gneiss.

In the following description we shall retain the general division mentioned in § 80, *i. e.* of simple and mixed rocks, and merely enumerate the most important kinds, with a description of their most striking characteristics.

I. SIMPLE OR HOMOGENEOUS ROCKS.

83. These have already been described in the first part of Mineralogy. We will therefore merely recite here the names of those which are most important, and add the sections of mineralogy in which they are described. Those the names of which are printed in italics occur in large quantities.

1. *Rock-salt*, § 34.
2. *Gypsum*, § 36.
3. *Limestone*, § 37.
4. *Dolomite*, § 40.
5. *Spathic Ironstone*, § 55.
6. *Pitchstone*, § 50.
7. Obsidian, § 50.
8. Pearlstone, § 50.
9. *Felsite*, § 50.
10. *Quartz*, § 31
11. *Augite Rock*, § 42.
12. Hornblende Rock, § 42.
13. Talc Slate, § 52.
14. Chlorite Slate, § 52.
15. *Serpentine*, § 41.
16. *Brown Ironstone*, § 54.
17. *Red Ironstone*, § 54.
18. *Magnetic Ironstone*, § 54.
19. Graphite, § 30.
20. Anthracite, § 30.
21. *Coal*, § 30.
22. *Brown Coal*, § 30.
23. *Peat*, § 30.
24. Asphaltum, § 72.

II. MIXED ROCKS

a. Crystalline Rocks.

25. CLAY-SLATE.

84. This rock is an indistinct mixture of very minute particles of mica, a little quartz, felspar, and talc, containing sometimes particles of coal, hornblende, or chlorite, and having mostly the appearance of a homogeneous mass. It is distinctly slaty, and has a fracture varying from splintery to earthy. It occurs of a greenish-gray, bluish-gray, violet, red, brownish-black, and, when decayed, sometimes yellowish-gray colour. When pulverised it is mostly white, but when coal is present it is black. Chiastolite, staurolite, garnet, tourmaline, and iron pyrites, are accidental constituents of this rock.

Varieties: common clay-slate; greywacke-slate; *roofing-slate*, which has a dark gray colour, and is used for covering roofs, and for writing-slates; whetstone-slate; *pencil-slate*, which is used for slate-pencils, and, as it contains frequently a considerable quantity of carbon which renders it sufficiently soft to impart its colour to paper, it is also employed as natural black chalk for drawing. *Alum-slate*, containing a considerable quantity of carbon, iron pyrites, and alumina, is used for the manufacture of alum.

26. MICA-SLATE.

85. Mica-slate is a distinct mixture of mica and quartz in alternate layers, the mica frequently enclosing small laminæ of quartz. It occurs slaty and of different colours, as gray, white, yellowish, reddish, brownish; and is lustrous. Among the accidental constituents are found the following:—garnet, talc, chlorite, felspar, hornblende, tourmaline, staurolite, iron pyrites, magnetic iron ore, and graphite. It passes over into gneiss, clay-, talc-, and hornblende-slates. The mica is sometimes replaced in this rock by other minerals, the following kinds of rocks being thus produced: talc- and iron-mica-slate; *itacolumite*, or flexible sandstone, from the mountain Itacolumi in the Brazils; also tourmaline-slate.

27. Gneiss.

86. This kind of rock has derived its name, which is without any particular meaning, from the language of the miners. It is a mixture of quartz, mica, and felspar. The quartz and felspar form granular layers, separated by laminæ of mica. It is slaty and of various colours, as gray, whitish, yellowish, reddish, greenish, &c. It forms the transition between mica-slate and granite. Accidental admixtures are: garnet, tourmaline, epidote, andalusite, iron pyrites, graphite, &c.

Talc-gneiss contains talc in the place of mica.

28. Granite.

87. The granular aspect of this rock acquired for it, at an early date, the above name, which is derived from the Latin *granum* (grain). Granite is a mixture of quartz, felspar, and mica, in which, however, the laminæ of the latter do not lie parallel to each other, thus preventing a slaty structure; it occurs of different colours, as gray, reddish, yellowish, greenish, and white. Accidental admixtures are: tourmaline, hornblende, andalusite, pinite, epidote, garnet, topaz, graphite, magnetic iron ore, tin ore, &c. It forms transitions between gneiss, syenite, and porphyry.

We may mention the following varieties of this rock:—*Porphyritic granite*, containing single large crystals of felspar; *graphic granite*, so called on account of its marks, which bear a resemblance to writing, and which are formed by the close intermixture of the quartz and felspar: *protogine*, a mixture of quartz, felspar, and talc; *granulite*, mostly a slaty mixture of felsite and quartz; *greisen*, a mixture of quartz and mica, containing usually tin ore and arsenical pyrites.

Granite is particularly adapted for constructing roads on account of its hardness; it is less suited for building, being rather difficult to work. It is frequently employed in large blocks for bridges, foundations of buildings, monuments, &c. Disintegrated granite yields a fertile soil.

29. Syenite.

88. Syenite is a distinct mixture of felspar and hornblende, frequently associated with quartz and mica; the entire mass might, therefore, be called hornblende-granite. An admixture of very minute crystals of titanite is likewise characteristic of this rock; it is granular, and of a reddish, or greenish colour. Its accidental admixtures are the same as those of granite. It forms transitions into granite, hornblende, and porphyry. *Porphyritic* and *slaty syenite* are varieties.

Syenite is applied to the same purposes as granite, to which it is, however, preferred for ornamental architecture, on account of its being more beautifully marked. The numerous and great architectural monuments in Upper Egypt are constructed of a reddish syenite, from *Syene*, from which locality the name of the rock is derived.

30. Greenstone.

89. This rock, likewise designated as *greenstone-slate* (trap, diabase, whin-

stone), is either a distinct or indistinct mixture of amphibole (bronzite, hypersthene, schillerspar), with felsite, and is either granular or compact, slaty and porphyritic; sometimes it is vesicular or amygdaloidal, the vesicular cavities being filled with calcareous spar. The colour varies from green to black; sometimes it is dark gray. The more frequent accidental admixtures are: iron pyrites, quartz, mica, garnet, epidote, and magnetic iron ore. The amygdaloidal and other greenstones that occur abundantly on the banks of the Clyde, in Scotland, abound with beautiful minerals belonging to the zeolitic class. The localities of Kilpatrick and Kilmalcolm are particularly famous for prehnite, Thomsonite, cubicite, mesotype, harmotome, stilbite, and other minerals of this class. Its varieties are: *diorite*, a distinct mixture of hornblende and albite, frequently with iron pyrites (the same rock of slaty structure is called *diorite slate*); *aphanite*, a compact and apparently uniform mixture, containing amphibole and albite, sometimes amygdaloidal, and when there is a preponderance of separate crystals of albite or hornblende, forming a transition into aphanite-porphyry; *gabbro*, a granular mixture of Labrador and diallage, sometimes containing titanic iron and serpentine; *wacke*, a brownish or dirty greenish rock, varying from compact to earthy, sometimes vesicular, slaggy, or amygdaloidal, originating most likely in the decomposition of various kinds of greenstone. The different kinds of greenstone are used for building, and some of them, which partly pass over into the porphyry variety, are employed in works of art under the name of *porfido verte antico*. Greenstone, on account of its extreme toughness, offers a valuable material for the formation of macadamised roads.

31. Porphyry.

90. Porphyry is a compact felsite mass, containing single crystals of felspar, quartz, more rarely mica or hornblende, and, accidentally, garnets or iron pyrites. Its structure is porphyritic (comp. § 81); it occurs of a reddish, yellowish, brownish, and variegated colour. Several works of art constructed by the ancient sculptors in stone, designated by this term, do not agree with what is now termed porphyry.

All kinds of porphyry are much used for building, for roads, &c. By disintegration they generally yield a very fertile soil, containing potassa. The different varieties are: *quartz-porphyry*, or red porphyry (*porfido rosso antico*), consisting of a compact mass of felsite, with crystals of quartz or felspar, and being mostly yellow, red, or brown; *mica-porphyry*, a mass of compact felsite, with crystals of mica and felspar; *syenite-porphyry*, a mass of compact or crystalline felsite, with crystals of felspar and hornblende; *pitchstone-porphyry*, chiefly composed of pitchstone, encloses crystals of vitreous felspar and quartz.

It is worthy of remark that several of the finely-spotted porphyries are employed in the construction of works of art, such as columns, slabs, vases, urns, bowls, &c. not unfrequently of extraordinary size. The most celebrated are the porphyry works of Elfdalen, in Sweden, and of Kolywan, in Asiatic Russia.

32. Melaphyr.

91. This rock may likewise be called augite-porphyry, or black porphyry,

and some of it amygdaloid. It is a compact, or somewhat crystalline, and mostly indistinct mixture of augite and Labrador felspar, frequently porphyritic, with single crystals of Labrador and augite, and of a dark brownish, greenish, or black colour. Accidental constituents of this rock are mica and iron pyrites, but *never* quartz. We may mention as varieties the compact, the *porphyritic melaphyr*, and likewise *amygdaloid*. The latter contains in its generally uniform mass vesicular cavities, partly or wholly filled up. These cavities are either irregular in shape or spherical, or oblong in one and the same direction, or they are pear-shaped, with the tapering extremity undermost. No doubt can be entertained that these cavities originated in an evolution of gas from the interior of the rock. The contents of the vesicular cavities consist of calcareous spar, calcedony, agate, quartz, zeolites, chabasite, &c. The layers or nodules of these crystals are in some cases parallel to the sides of the cavities; in others they exhibit irregular masses, and sometimes they assume botryoidal or stalactitical forms.

Melaphyr is likewise used for building and for roads. It does not easily decay, but when it is disintegrated it yields a very fertile soil.

33. Basalt.

92. This rock is generally an indistinct mixture of augite and felspar; it is also called *basanite*, and some kinds of it have received the name of trap. The above constituents are generally associated with olivine and magnetic iron ore.

Basalt is compact, porphyritic, granular, amygdaloidal, and slaggy; its colour is either black, greenish, grayish. or brownish-black. It is commonly hard and heavy. A distinction is made between the common basalt, which is compact and apparently uniform in mass, and *dolerite*, a distinctly mixed basalt, in which we recognise especially augite and felspar. The accidental constituents are nepheline, leucite, mica and iron pyrites, besides olivine and magnetic iron ore. The *amygdaloidal basalt* contains vesicular cavities. Basalt furnishes the best material for paving roads. For building, the compact basalt is too heavy, while on the other hand the porous basalt is well adapted for this purpose; it is not applied to finer works of art. The latter kind is met with in Germany, in the vicinity of extinct volcanos, especially in the seven mountains, in the most southern parts of the black forest (Kaiserstuhl), and in Bohemia, where it is used as dry building stone, and the lighter variety in the construction of cupolas and vaults. The porous basalt, from the quarries in the neighbourhood of Coblentz (at Niedermending), is much celebrated, and is employed for millstones. When disintegrated by atmospheric influences, basalt yields a highly fertile soil, which is particularly warm on account of its dark colour.

34. Phonolite.

93. This rock is called klingstein, or sounding stone, from its property of producing a clear sound when struck with a hammer, and though apparently uniform, it is a mixture of felsite and natrolite; it occurs compact, laminated, porphyritic, from crystals of felspar, but rarely vesicular. The fracture varies from splintery to conchoidal, and from vitreous to earthy. The colours

of this rock are greenish-gray, gray, and blackish-gray. A peculiarity of this kind of rock is, that nearly all its surfaces exposed to the atmosphere are coated with a white crust of the disintegrated stone. The accidental constituents are: hornblende, augite, magnetic iron ore, titanite, leucite, and mica. The drusic and vesicular cavities generally contain, moreover, zeolites. This rock passes over into trachyte, and approaches on the other hand to basalt. As varieties we may distinguish compact phonolite, porphyry slate, and the decomposed phonolite, which is a soft almost earthy rock, and yields a kind of porcelain earth, like the above-mentioned white crust of disintegrated rock. This rock, which frequently splits into plates, is used in building, sometimes even for roofing, but rarely for the construction of roads. The clay soil resulting from its decomposition is but little favourable to agriculture.

35. Trachyte.

94. Trachyte is an indistinct, indefinite, mostly granular mixture, in which felsite predominates. It is nearly always porphyritic, from the presence of vitreous felspar crystals, and generally contains scales of mica and needles of hornblende. It occurs granular, porphyritic, compact, slaggy, and earthy. The fundamental mass is gray, yellowish, reddish, or greenish. For building purposes this rock may easily be dressed with the hammer and other suitable tools; but it decays easily, as has been proved, for instance, in the cathedral at Cologne, the more ancient part of which is constructed of trachyte, from the Siebengebirge. It yields on the other hand a fertile loamy soil for agriculture.

36. Lava.

95. This is an indistinct mixture of augite and felsite, frequently associated with leucite and magnetic iron, more rarely with mica, olivine, &c. It occurs granular, compact, porphyritic, and slaggy. Its colour is either dark, brown, gray, reddish, greenish, yellowish, or black. All the glowing masses in general that are emitted in streams from volcanos during eruptions, independently of their composition, are called lavas. The different varieties are —the *basaltic lava*, very similar to basalt, though rougher; *doleritic lava; leucite lava; porphyritic lava; slaggy lava;* and, lastly, the *volcanic scoria*, consisting of detached fragments, and called *lapilli*, or volcanic sand. Lava is particularly distinguished for the remarkably fertile soil it yields by slow decomposition. This may be a consequence partly of its chemical constitution, partly of its dark colour, and of the evolution of heat and carbonic acid from the ground near volcanos still in action.

b. Mechanically Mixed Rocks.

I. Distinctly Mixed Rocks.

37. Breccia.

96. Breccia is a combination of angular fragments of rocks, united within another mass, which may be termed the combining medium, or cement. These breccias receive different names, according to the fragments they con-

tain, or to the uniting medium. Thus we distinguish, *e. g.* granite-, porphyry-, limestone-, and bone-breccias. From the supposition that some breccias have arisen through the forcible trituration of a liquid mass against a solid one, they are called *trituration-breccias*, as, for example, a mass of porphyry with fragments of clay-slate.

When the uniting medium of the breccia is sufficiently hard, it may be used for building material. A few breccias, which, from the admixture of variegated and differently formed fragments of rocks, present a very beautiful appearance particularly when polished, are used in ornamental architecture, and receive different names, answering to their appearance. Thus a breccia, consisting of granite, porphyry, and diorite, is called *breccia verde d' egitto*, and the various marble breccias are named *violetta antica*, *dorata*, *paronazza*, &c.

38. Conglomerates.

97. *Conglomerates*, or pudding-stones, are distinguished from breccias by the *rounded* water-worn form of the rocky fragments or pebbles which are cemented together. They have received various names, according to their constituent fragments: for instance, gneiss-conglomerate, basalt-conglomerate, *greywacke*, *nagelfluh*, &c. Conglomerates may be used for building and road-making. They, as well as the breccias, yield on disintegration a soil, the fertile quality of which must, of course, depend upon the nature of the rocks composing them. Thus greywacke-conglomerate yields a stoney, and therefore loose, clayey soil. The red conglomerate has a sandy or clayey combining medium, containing layers of porphyry, gneiss, granite, mica-slate, clay-slate, &c., which remain undecayed in the clayey and sandy soil. Basalt-conglomerate generally yields a very fertile loam- and clay-soil.

39. Sandstone.

98. This rock, so universally distributed and so well known, is a combination of minute and mostly spherical particles, held together by a uniting medium which is scarcely to be distinguished. Sandstone is granular, and occurs of all colours. The particles are principally quartz, and the cement is generally clay, marl, or oxide of iron, and more rarely hornstone. We distinguish accordingly *clayey*, *calcareous*, *marly*, *ferruginous*, and *siliceous sandstone*.

We call it *conglomerate* sandstone, if it contains isolated and large rubble-stones. Besides grains of quartz, it sometimes contains scales of mica or grains of felspar, hornblende, or green earth. The latter imparts a green colour to it, and hence the name *green sandstone*. There are various other admixtures in sandstone, of which we will merely mention the globular concretions of clay, which are termed *clay-galls*. Many other names given to sandstone, such as keuper sandstone, lias, &c., refer to the stratification, which we shall describe farther on.

In sandstone we possess one of the most valuable materials for manifold purposes. It is particularly adapted for building, being very workable. Sandstones of finer grain and uniform colour offer an excellent material for sculpture, and have been employed especially in the rich and magnificent ornaments of our ancient cathedrals. The colour of sandstone ranges from

white through yellow, greenish-yellow, to brownish and brown,—the latter variety being found of great beauty in Würtemberg. Besides these, red sandstone is also frequently found.

Sandstone is but little suited for the construction of roads; but the hardest kinds are used for millstones, grinding stones, and many in the form of flags are used for roofing and paving.

The soil it produces by disintegration is one of the most unproductive, since it is totally destitute of potassa and soda, and incapable of retaining moisture. Sandstone, in which clay and marl preponderate as a cement, is, of course, more favourable to agriculture.

40. Debris. Gravel. Sand. Crumbled Rocks (Gruss).

99. The term *debris* is applied to a loose accumulation of rocky fragments, which may be considered as breccias without cement. By *gravel* or *rubble-stones*, on the other hand, we understand an accumulation of rounded fragments of rocks. It may consequently be regarded as conglomerate without a binding material. *Sand* is a loose accumulation of mineral grains consisting chiefly of quartz. *Gruss* signifies the loose, unconnected constituents of any rock, *e. g.* granite-gruss consists of a loose mixture of grains of quartz, mica, and felspar.

II. *Indistinctly Mixed Rocks.*

41. Marls.

100. Although apparently uniform, marls are an amorphous mixture of carbonate of lime and of clay, occurring of all densities, from compact to earthy, also slaty, but rarely of a fine grain. The colour of marls is either gray or yellowish, reddish, greenish, bluish, black, white, or variegated. They crumble to pieces in the air, generally very rapidly, and effervesce slightly with dilute hydrochloric acid. According to the preponderance of one or the other constituent, or to the admixture of other minerals, we distinguish *common marl, calcareous marl, clayey marl, silicious marl, sandy marl,* and *bituminous marl,* which is mixed with bitumen (asphalt), and frequently occurs slaty; finally, we meet with *cupriferous slate,* a bituminous marly slate of black or dark-gray colour, which is famous for abounding in those copper ores, mentioned in § 59, and which contains besides cobalt-, nickel-, and silver-ores.

Marl is totally unfit for building purposes, in consequence of its rapid disintegration; it is, however, on this account the more valuable in agriculture. Marl soil is considered the most fertile, but it must be observed that it should not contain under 10 nor above 60 per cent of carbonate of lime. Poor sandy and calcareous soils are improved by a dressing of marl. The marl containing a larger proportion of lime, is also burned and used as hydraulic lime or cement (comp. Chemistry, § 81). Marls are principally found in districts of the more recent formations, *e. g.* in Suabia.

42. Clay.

101. *Clay,* though apparently uniform, is a mixture of alumina with a little lime, and silica (comp. Chemistry, § 87). It occurs compact, earthy,

soft and friable; it softens in water and is exceedingly plastic. It is found of all colours, and sometimes even black, owing to the presence of bitumen. We distinguish besides pale common clay, yellow loam, and a loose earthy mixture of clay, lime, and sand (löss), of yellowish-gray colour, distributed more particularly throughout the valleys of the Rhine. *Saline clay* is mixed with rock-salt, and has a dark colour, which is due to the presence of carbon.

Only the clay of the more ancient formations, hardened into stone, is used as a building material. Respecting the use of plastic clay, we have given many details in § 88 of Chemistry.

43. Fuller's Earth.

102. This term denotes a soft friable mass, probably derived from the decomposition of greenstone; it possesses an uneven fracture, from coarse to fine earthy, and is unctuous to the touch. Its colour varies from gray, greenish, and yellow, to white. It forms with water a thin unmouldable paste, which is used by manufacturers for extracting the greasy matter from woollen fabrics. It contains about 10 per cent of clay and up to 60 per cent of lime, and is closely related to the boles.

44. Tufa.

103. Under this name are comprehended several kinds of rock, not accurately defined; they contain rather loose and partly earthy combinations of clayey, calcareous and sandy constituents. Their colour is mostly gray or yellowish; sometimes they also enclose fragments of compact rocks. Amongst other tufas we notice the following, viz., *trass*, a volcanic tufa, which, mixed with $1\frac{1}{2}$ to $2\frac{1}{2}$ parts of lime, forms a cement which sets under water (Chemistry, § 81), and hence has been applied to many important purposes. The trass from the neighbourhood of Andernach is the most celebrated in Germany. The volcanic tufa of Italy, *pausilipp tufa* and *peperine*, or pepperstone, are partly applicable for building; but they are sometimes much injured by the influence of the weather. In the neighbourhood of Naples there exist antique buildings, grottos, &c., constructed of this rock. By disintegration it produces an extremely fertile soil.

45. Humus.

104. Soil is the superficial stratum of the earth's crust. It is mineralogically undefined, and must be considered as the result of the combined influence of plants and animals upon the mould yielded by disintegration of any kind of rock. The remains of decaying organic substances (comp. Chemistry, § 165) are intimately mixed with the particles of the crumbled rock, and impart to them mostly a darker and sometimes a black colour, and highly fertilising properties. Some localities of the earth, however, are entirely destitute of this mould; for instance, where pure lime- or quartz-rock forms the surface, vegetable life, in consequence of the deficiency of nutrition, is either totally absent, or if present, it is developed so imperfectly that humus or organic matter cannot be formed on such soils.

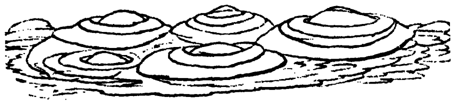
B. CONFIGURATION OF ROCKS.

105. When a mass of any variety of rock is before us, there are two modes of considering it with reference to its form; firstly its configuration and relation to external objects, and secondly its interior structure. We accordingly distinguish the internal and external forms of rocks.

Internal Forms of Rocks.

106. We do not anywhere find masses of rock of any extent equally coherent throughout. Even in the most compact and hard kinds we observe divisions and fissures. The origin of the latter may easily be illustrated by a mass of moist clay. As it dries it contracts, and in consequence cracks and fissures appear on the surface. This may frequently be perceived on a large scale in all clay-soils during hot summers. Hence the rocks must originally have been soft; as they hardened they contracted, and became in consequence more or less split or cleft—thus giving rise to *irregularly massive* and *fissured* rocks.

The segregation of the rocks frequently takes place with wonderful regularity: so that the rocks resulting from the splitting of the primary mass present the appearance of a structure built by man. There are also rocks enclosing globular concretions, arising from the circumstance that the hardening of the mass began in different central points, round which further deposits were formed in concentric layers. Thus when trap-rock is exposed to the weather, the surface suffers disintegration, and peels off, in thin layers, like the concentric coats of an onion, often exhibiting large round masses on the surface of the rock (fig. 1). Occasionally the rounded masses are so small, that the rock has the appearance of a quantity

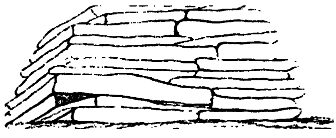


1. Disintegrating Surface of Trap-Rock at Corrie, in Arran.

2. Giant's Causeway, County Antrim, Ireland.

of pea-iron ore. More frequently rocks are split up into pillars, having generally the form of hexagonal columns. Such columnar formations are beautifully illustrated by the basaltic columns of Fingal's Cave, in the Isle of Staffa, and by the Giant's Causeway (fig. 2), on the west coast of Antrim, in Ireland. Similar formations occur near Stolpen, in Saxony, and at Unkel, on the Rhine, where columns of the length of from 30 to 80 feet have been observed. These columns are frequently separated into smaller pieces, in which case they are said to be *jointed.*

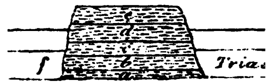
The most common form into which rocks are split is in flat or tabular masses (fig. 3). The resulting tabular masses are more or less regularly defined, and frequently so thick as to form blocks of immense size; or they appear as slabs gradually attenuating to flags.



3.

STRATIFICATION.

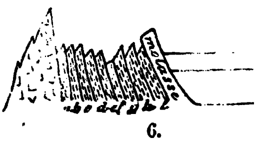
107. Stratified rocks frequently show, by their structure, that the superincumbent layers did not originate at one and the same period, but that their deposition, solidification, and contraction took place, consecutively. This is rendered evident by the circumstance, that between strata of the same kind, intermediate layers are often observed; for instance, beds of limestone are separated by others of marl. We have abundant evidence that rocks stratified in this manner, arose by a gradual settlement of their particles, originally held in suspension by water, according to their greater specific gravity. Similar formations of layers or strata may still be daily observed on a smaller scale on the banks of our brooks and rivers. Having in the following pages to return to the origin of stratification, we will here consider some peculiarities of the strata or of their relative position.



4.

The different layers of a stratified rock, as shown in fig. 4, have a parallel position like the leaves of a book. The thickness or *depth* of the individual strata is exceedingly unequal; for some of them, as represented by lines in the diagram, measure scarcely a quarter of an inch, and are interposed between others that measure from 20 to 30 feet in thickness. The direction of these strata is either horizontal, *i. e.* parallel to the surface of the earth, as in fig. 4; or in an inclined position, as in fig. 5. Various strata are likewise occasionally observed to have a vertical position, as in fig. 6, in which case they are called *vertical* strata. The course in which water poured on an inclined stratified layer would descend, is called, in geological language, the fall or *dip* of the strata. The direction of various strata is designated by the term *strike.*

5.



6.

Those parts of strata which first come to the surface of the earth, as shown in

figs. 4, 5, and 6, are said to *out crop* or *basset*. The exposed or superficial parts of erect and inclined strata, as in figs. 5 and 6, are also called their *heads*. The vertical sections become exposed mostly by the action of currents of water, rivers, &c., as in fig. 7, or by the action of the sea; and also by making railroads, quarrying, and mining.

Various strata are frequently observed to taper off, and to decrease considerably in thickness in one direction, at last either ceasing entirely, or extending farther in scarcely recognisable laminæ between the other rocks. This occurs especially with beds of coal, the discovery of the wedge-like end of which frequently leads to beds of greater thickness. It is called thinning out.

From this it will be evident that various strata may appear in one place to be in almost immediate contact, whilst at a short distance farther they are much farther separated from each other.

The erect or inclined strata are evidently not in their original position, but have been forced out of it by some cause acting subsequently to their formation. This is, however, not the only alteration which certain strata have suffered, for their regular and parallel course is often more or less interrupted, and in that case they appear no longer equally superimposed like the leaves of a book, but are bent, twisted, broken up, and intermingled.

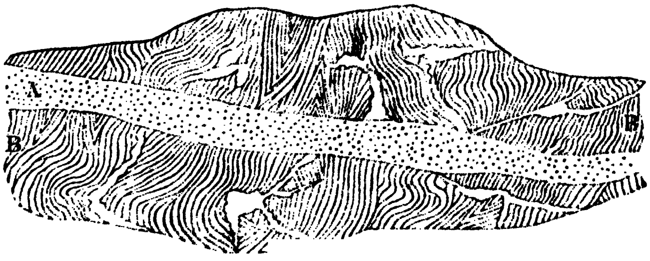
External Forms of Rocks.

108. If we contemplate the general aspect of rocks in relation to surrounding objects, they present themselves under three different forms, namely, a *Stratified* rocks, *Massive* or *Igneous* rocks, and as *Veins*.

In general several strata of different kinds of rock are perceived to overlie each other, and form in this manner systems of stratification, frequently of very considerable extent. Limestone, Dolomite, Coal, Sandstone, Clay, and Marl, afford special examples of such stratification.

The structure of the *igneous rocks* never exhibits the slightest appearance of stratification, but merely an irregular cleavage, and the segregations mentioned in § 106. They are rarely spread over any considerable space, but occur as isolated steep masses breaking through the stratified rocks, and interrupting more or less their regular arrangement. Granite, syenite, porphyry, basalt, &c., exist merely as massive rocks, and never occur stratified.

Veins penetrate not merely through the stratified, but also through massive



8.

Vein of Granite penetrating contorted strata of Mica-slate near Goatfell, Island of Arran A, Granite. B, Slate.

rocks. Their form may be readily understood by studying their origin. In the chasms and fissures which arose during the process of hardening and contracting of the other kinds of rocks, there penetrated afterwards soft mineral masses which, in course of time, likewise hardened. These veins are rather irregularly distributed; here also their dip and strike are likewise to be taken into consideration. These veins must, however, be distinguished from the *mineral* or *metallic veins*, which are generally of inferior thickness, but of more importance, since they contain valuable minerals and ores, and are therefore frequently mined.

Special Forms of Rocks.

109. As such we have to mention formations frequently observed in the caverns of several parts of England, particularly Somersetshire and Derbyshire. These are called *Stalactites* (fig. 9), if pendant from walls, and increasing downwards like icicles, or *Stalagmites*, if arising from the ground, and increasing or growing upwards by the accumulated droppings from above. They generally arise from calcareous water, which trickles through the roofs and sides of caverns, and on evaporating leaves the lime behind in the most singular and varied shapes. *Petrefactions* are formed by the evaporation of waters, holding minerals in solution, upon any object, which thus becomes covered with coatings of various thickness. We find frequently tracings resembling trees or mosses between slabs or plates of rock, forming *Dendrites* (fig. 10), which may easily be imitated, and their origin illustrated by placing some finely levigated clay between two plates of smooth glass, or stone, and pressing them slightly together. A variety of ramified designs are thus obtained, similar to the hardened formations occurring in Nature, which may easily be mistaken for petrified moss or other vegetable objects.

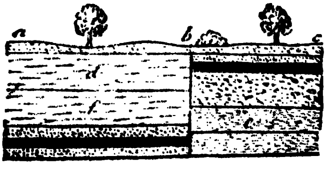
Stalactites and Stalagmites.

10.
Dendrites.

C. STRATIFICATION OF ROCKS.

110. From the relative position of the strata, masses, and veins, we are enabled to identify the relative periods of their formation, or deposition.

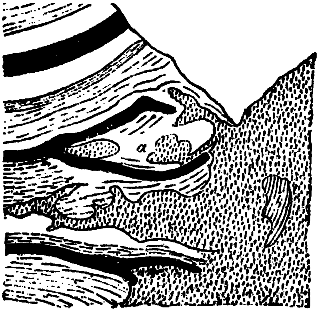
The relative position of the strata to each other, may be very different. For instance, they may be lying horizontally and parallel to each other (fig. 11), or they may assume an inclined or vertical position (fig. 12), covered by parallel horizontal stratifications.



11.

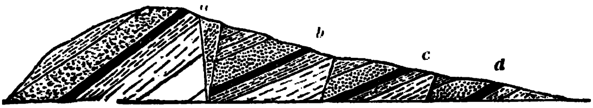
12.

Massive rocks generally are found rising side by side, and it rarely happens that one is covered over to any extent, by the horizontal layer of another. Trunk- and *clod-shaped* rocks are often intermixed with each other; as for example, granite by gneiss (fig. 13), which often occurs when the interior rock, in its eruptive ascent, breaks off and carries along with it fragments of the other which it entirely encloses.

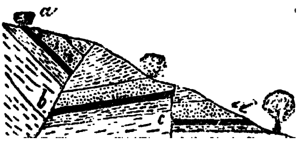


13.

Veins generally extend more in a vertical direction towards the interior of the earth, than in horizontal or oblique directions. They are frequently found to pass through the rock almost perfectly parallel with each other. By a disturbance of the position of the main rock, these veins are of course likewise displaced and broken up, which gives rise to great difficulties in mining, in following up a rich vein of ore. The lodes also cross and pass through each other. The coal measures of



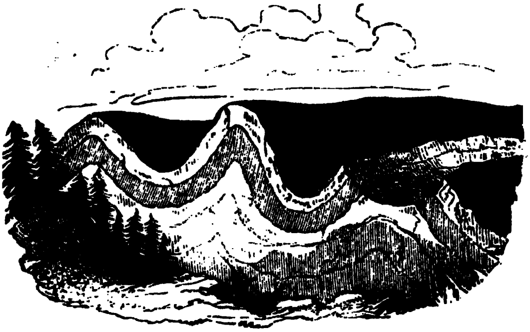
14.



15.

Great Britain are frequently seen to have been dislocated by *faults*. This will be easily understood by referring to figs. 14, 15, in which *a*, *b*, *c*, *d* represent coal measures, which have been displaced from their original position, by subterranean disturbing influences.

Fig. 16 represents a very remarkable example from the Jura mountains, where, owing to the flexibility of the strata, they have suffered great contortion, *without* becomıg ruptured, so as to produce faults.



16.

111. From a closer observation of the above-mentioned relative position of rocks, we gather the most important conclusions, as to which of them is the older, or, what amounts to the same, which formation was deposited first. The following principles may be accordingly accepted as perfectly established. The upper strata are newer,

or of more recent date than those which are below them; rocks which have disturbed the position or stratification of the adjacent formations are more recent than these; rocky masses in the middle of other rocks from which they are separated by sharply defined lines, are generally of more recent formation than the latter; rocks which enclose fragments or disjointed layers are more recent than those from which the fragments are derived; veins and lodes are more recent than the beds of rocks in which they are found, and also, than the veins which they cross or intersect; and, finally, if one stratum of rock is of later date than a second and older than a third, the second must be likewise older than the third.

D. FOSSILS.

112. Many rocks enclose fossils, which may be recognised at a glance, as not being of mineral origin, but to have belonged formerly to the vegetable or animal kingdom. Hence it follows that the origin of the rocks themselves must be dated from the same period in which those plants and animals existed. The petrifaction of these organic bodies has not been the result of a transformation of their chemical constituents into those of a mineral character, since that would be impossible, as has been shown in Chemistry (§ 10). On the contrary, these plants and animals, during the mighty revolutions of the earth's crust, became enveloped in semi-fluid masses which have subsequently hardened into the rocks in which they are now found. It is evident that under such violent processes the softer and more perishable parts could not be preserved, and hence, in general, only the more durable parts of plants, such as bark, wood, and ligneous fruits, and the calcareous shells of corals, mussels, and snails, as well as the bones of the higher class of animals, remain. The more perishable organised formations, consisting of carbon, hydrogen, and oxygen, have undoubtedly been sooner or later decomposed, since they are never found in the rock. Nevertheless, under favourable circumstances, many an indication or evidence of these formations has been preserved in the midst of destruction. Delicate leaves, and minutely articulated insects enveloped in the semi-fluid mass, have at least left behind impressions in the hardened rocks, from which their structure and class may often be clearly traced. In other specimens the innumerable little interstices or cavities of their bodies have been gradually filled up with a mineral fluid, which, upon hardening, preserved the form of the body.

113. Difficult as it was at first to explain the appearance of an innumerable host of organic remains enclosed in rocks at great depths, and at altitudes of 12,000 feet, these fossils became at a later period most important, as characteristic of the various rocks in which they occur. The following facts have resulted from accurate observations of these remains.

Fossils are found only in *stratified* rocks, which have been deposited from water, and never in massive rocks. The number of species, both of fossil plants and animals in the various strata, is very unequal: those occurring in the upper strata, approximate more closely to the still-existing species of the animal and vegetable kingdoms; these, however, decrease in the lower strata, in such a manner that the more perfectly developed animals and plants gradually disappear whilst the lower orders prevail, and the existing species become more and more rare. In the lowest and oldest strata,

only such fossil remains, of organised beings, are met with, as are now no longer to be found in the recent state.

If the formation of two beds of rock, in different localities, has on other grounds been proved to be contemporary, they will contain the same fossils; and, on the other hand, we conclude from the exact similarity of the species of fossils existing in two different rocks that they must be of contemporary origin. Hence organic remains have become of the utmost importance in ascertaining the age of different strata, and in some cases they are the easiest, and even the only means of deciding that question. As we find in the various strata the remains of a widely-differing vegetable and animal world, we conclude that the climate and condition of the surface of the earth, at the different periods of its formation, must have been very dissimilar. Again, the fossils of the oldest strata give evidence of the animal creation having been formerly much more equally spread over the surface of the earth than it is at present; and hence the great difference of temperature at the poles and the equator, seems not to have been so remarkable formerly, as it is at the present period.

114. The total number of fossil plants and animals is exceedingly great, and has become the object of two special sciences, namely, *Fossil Botany* and *Palæontology*. Their correct description requires of course a comprehensive knowledge of botany and zoology, and therefore, in treating of these sciences, we shall devote special attention to fossils. We will, however, introduce here a concise review of the plants and animals which occur as fossils, beginning with the lower or more imperfect orders.

Of *fossil plants*, we find the following orders: algæ; lichens; mosses; and *Equesetaceæ* occupying the oldest up to the mediæval strata. Lycopodiaceæ; *ferns* of the size of trees (which are, however, abundant only in the older strata); Liliacea; *palms*, stems, fruits and foliage; *pines* and *dicotyledonous trees;* the latter occur only in the more recent strata.

Fossil Animals.—*Infusoria* are found in many strata; polypi or *corals* occur most frequently in the oldest formations. Radiata and echinodermata, amongst which are found encrinites, starfish, and the common sea-urchin (*Echinus esculentus*), and *mollusca;* these are the most frequent of all, and to the geologist the most important. We find in the old strata, but more plentifully in the middle strata, not only bivalve shells but also univalve shells, and among the latter several important genera now perfectly extinct, as ammonites and belemnites. Annellata or fossils of the worm kind are rare; *crustacea* are likewise not of frequent occurrence. *Insects* occur distinctly only in beds of brown-coal, especially in amber: they are, on the whole, very rare. *Fishes* are exceedingly numerous, upwards of 800 species having already been recognised in the various strata. *Amphibious animals* are only rarely represented by batrachians and serpents, but frequently by animals of the lizard tribe, which are sometimes found of gigantic size. These, however, are now extinct. *Birds* are but seldom found in the older strata; *mammalia* exist only in the uppermost strata. There are, however, several extinct species of gigantic size, including the mammoth, megatherium (page 330), dinotherium, &c. Monkeys are exceedingly rare. Traces of human remains are not contained in any of those strata which have been subjected again at a later period to a general destructive influence. Man, therefore, did not appear on earth until its crust was sufficiently stable, and suffered no longer any general revolution.

SYSTEMATIC GEOLOGY.

ORIGIN AND STRUCTURE OF THE CRUST OF THE EARTH.

115. This wondrous edifice, inhabited by man, did not attain at once its present condition. Let us trace, from the preceding statements founded on experience and facts, the history of its origin and progress.

There was a time when the whole earth must have been a liquid glowing mass describing its course through space. The elements or simple substances which it contains then united with each other only in such combinations as could exist at that high temperature. The gases formed the atmosphere which surrounded the denser nucleus of the earth; with this was associated the vapours of an immense number of volatile compounds which could not exist in a solid or liquid state at such a temperature. The ocean was then in the form of vapour. Thus the earth in its first phases of formation appears to have been a soft, red-hot nucleus, enveloped by an immense and very dense atmosphere which surrounded it or followed its course, perhaps in the same manner as the vapoury spheres or tails of the comets and nebulous stars appear now to accompany these bodies through space.

By continually radiating heat into infinite space, the earth, at least on its surface, diminished in temperature. The difficultly fusible chemical compounds, such as silicate of alumina and magnesian clay-slate (mica-slate), &c., began gradually to separate in the form of finely laminated crystals, and by continued cooling, to settle upon the surface of the nucleus of the earth, forming the first thin coating or crust over the red-hot liquid mass, and thus separating it from its vapoury atmosphere. This was the commencement of the earth's crust, which might now be increased in firmness more rapidly since the immediate influence of the internal heat upon the atmosphere was arrested, and since the combinations, existing in form of vapour, could be deposited thereon, at least partly, in the form of liquids.

116. At that time organic life could not exist. The crust was still too hot to admit of plants taking root and growing; the existence of vegetation, however, is indispensable to animal life, and indeed those lower slaty strata, consisting of mica-slate and clay-slate, contain nowhere the least trace of animal or vegetable matter. If water had gathered already at that period upon the crust of the earth, it must have possessed a much higher temperature than at present: hence it was capable of dissolving numerous chemical compounds; and while the ocean at present contains only the easily soluble common salt, &c., the ocean of that period may have held in solution great quantities of silicates, sulphates, and carbonates. It also broke up again a portion of the solid crust, and formed therewith a muddy liquid, which, however, as the earth cooled, again gradually deposited its solid parts in granular strata, forming what is now known as sandstone.

117. Thus we behold acting continually, in concert and by turns, the laws of chemical affinity and of gravitation, in obedience to the latter of which the more compact substances had a tendency always to occupy the lowest place.

Had this mode of formation thus regularly continued, the surface of the earth must have assumed a tolerably uniform shape; the eye would have beheld neither hills nor valleys; the main body of the earth would have been

covered all round by a shallow ocean, and this in its turn would have been enveloped by the atmosphere. The surface of the earth, however, is differently formed. Repeated disturbances gave to it a more varying exterior. And what may have been the cause? The very same powers of Nature, which, by the same laws, prevail up to the present day, produced under the peculiar circumstances of that period, phenomena now scarcely conceivable.

118. The solid substances first deposited form what are justly called *fundamental* or *primitive rocks*, and the superincumbent deposits which occur in strata, are termed *aqueous* or *stratified* rocks; these generally consist of several dissimilar strata, forming together a *stratified system*. Whatever rocks originated within the same period we call *coeval formations*, and hence we speak of the oldest, the secondary, and the modern formations.

The crust of the earth, upon hardening and contracting, split into fissures and chasms similar to what we perceive frequently on a considerable scale in parched clay soils. The water entered these chasms, widening them more and more by its solvent power, and penetrated at last through the thin crust to the glowing interior mass. Let us picture to ourselves an immense quantity of water coming suddenly in contact with a red-hot surface—what must have been the result? The formation of a vast body of steam, which, by the intense heat, attained an extraordinary degree of expansive power. These vapours pressing in every direction with an irresistible force, raised the crust of the earth, puffing it up here and there in gigantic vesicles, which were finally rent asunder with a fearful crash, and from the opened abyss there poured forth the red-hot liquid mass. Convulsively propelled by the vapours thus liberated, it spread over the neighbouring surface or was formed into mountains surrounding the opening of the eruption.

119. Let us now cast a glance on the present surface of the earth. How different do we find it from that regular form described in § 117! From the uplifted portion of the earth's crust the waters have flowed to the lower parts. The solids have separated from the liquids; the former appearing as *continents* surrounded by islands, the latter as the *sea*. The land consists partly of stratified rocks, partly of an irregularly shaped mass, which has been forced up from the interior and slowly solidified, and which hence presents the appearance of an irregular mass of unstratified rock. The fissures that arose here and there in both formations were filled up with softer rocks or ores, and in this manner originated *veins*. (Comp. § 108.)

We have now recognised *water* and *fire* as the two grand agents by which these wonderful changes have been accomplished, and hence we call the one *Neptunic*, or water formations, and the other *Plutonic*, or fire formations, from the mythological representatives of water and fire.

120. The mountains of this period of primitive formation were not of considerable altitude, nor the seas of any great depth. The localities which had become dry were gradually covered with plants, and perhaps at the same period animals were created. Considering the thinness of the earth's crust at that time, both land and water must have possessed a higher temperature than at the present time, and hence only those beings were created that were capable of existing under such conditions. Fuci, polypi (corals), are the principal remains of the first living creations found in the oldest strata, then formed.

121. It is uncertain how long after this first revolution the earth's crust

remained in the condition then acquired. It may have been hundreds or thousands of years. The thickness of the strata gradually deposited, and the successive generations of animals, the remains of which lie over each other in the later formations, afford only relative indications with respect to this subject.

It is, however, certain that the first revolution was not the only one. Although the crust of the earth increased in thickness by its continual cooling, still the same causes have effected later eruptions, the essential phenomena of which we have already described. The tension and pressure of the vapours must, however, have become much greater from the increased thickness of the crust that confined them, and consequently the now compact strata have been raised to a much greater height, and the quantity of massive rock forced up through the openings has been much greater, and piled up higher than on their first formation.

The massive rocks of the earlier formation must, however, have been frequently pierced by those of the subsequent periods, while the reverse of course could not take place. The waters destroyed at the same time a great part of the rocks and deposited them again in strata, the vegetable and animal world was overwhelmed, and here and there buried and fossilized. (§ 112.)

122. Thus several revolutions followed each other at increasing intervals of time. For each later one a greater lapse of time was required in proportion to the increasing thickness of the crust of the earth, before new fissures allowed the water again to penetrate into the interior of the earth. The result was, however, all the more powerful, and the displacement of the strata previously formed, as well as the rising masses of Plutonic rocks, were so much the more considerable. It is an ascertained fact that the *highest* mountains of the earth, the Andes, Cordilleras, Alps, &c., are at the same time the most recent, that is to say, the latest which have been upheaved.

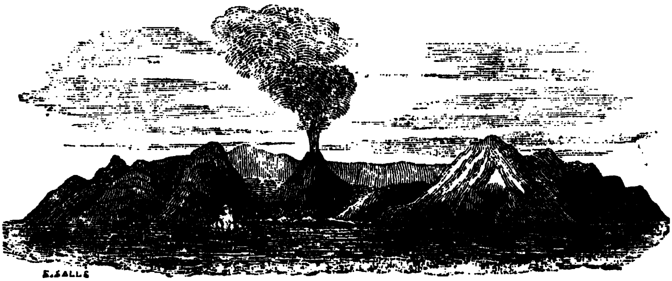
123. Each of these mighty revolutions was terminated by the closing up of the fissures and chasms in the crust of the earth, partly through the continued cooling of the interior mass, partly by being filled up by aqueous or muddy deposits from without. In some places this was effected perfectly, in others less so, and probably in the latter a new eruption was occasioned at a later period.

But even after the termination of the last general upheaval not all the fissures, leading to the interior, were perfectly closed. In isolated localities where these chasms happened to be very wide, or where mighty rocks accidentally had left gaps between them, these openings into the interior were preserved and exist up to the present day. They might properly be compared to the shafts of our chimneys which lead from the exterior of a house to the fire-place.

Such openings in the earth are called *volcanos*, fig. 17. Their operations and effects are pretty well known and easily understood from the previous statements. If their shafts were empty we should be able to look down them to the glowing bowels of the earth; but these hollows or *craters* are covered with cooled and hardened masses of rocks called *lava*, and with other *volcanic* formations.

From time to time the waters, in a manner not very difficult to explain, find access to the interior of these volcanos. The steam produced suddenly expands and causes what we call earthquakes, the convulsive effects of which frequently extend to great distances. They generally precede an eruption. The increasing tension of the steam will at last force the glowing mass upwards, together with its solid cover. The repeated rising and falling of the great

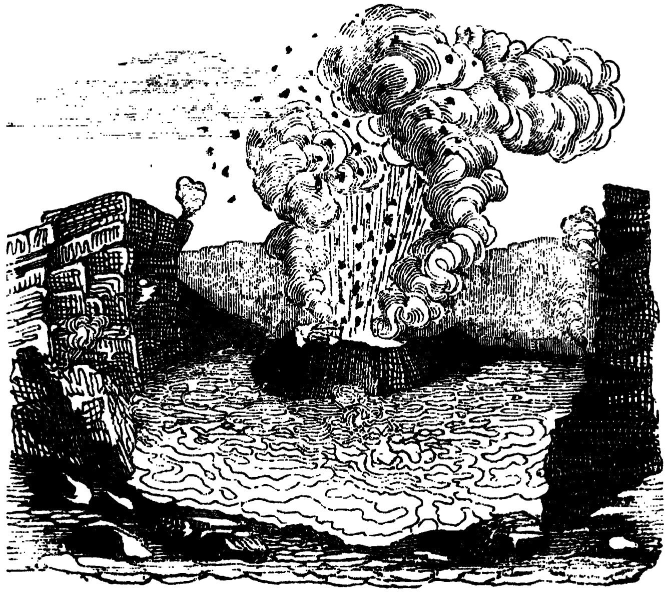
volumes of steam, their partial escape, and the violent commotion and vibrations of great masses of the earth, are always attended with terrific noise,



17. View of Barren Island, in the Bay of Bengal.

which may be compared at times to the continued rollings, and occasionally to the single claps of thunder. The red-hot and liquid mass being forced up finally to the mouth of the crater, its cover is immediately burst and thrown up towards the heavens, its fragments and dust being scattered in the air, and carried by the winds, as volcanic ashes, often to a distance of many miles, fig. 18. The glowing mass then rises more slowly and flows as a stream of lava over the margin of the crater, destroying irresistibly everything that lies in its path.

This terrific moment of the revolution includes, however, at the same



18. Crater of Vesuvius in 1829.

time the conditions of its termination. The steam having escaped, the calm in the interior is restored, and the ejected lava flows out more slowly; finally

the progress of the stream is interrupted, and the lava begins to harden, while the interior mass sinks down again to its original depth. Only steam, sulphurous vapours, &c., still escape from the crater, and hot fountains spring forth in its neighbourhood, indicating that all below is still glowing. A. von Humboldt truly designates volcanos as the safety-valves of the earth's crust.

The steam which escapes from the active volcano forms above it a cloud of dazzling whiteness, and gives rise to electric phenomena of the highest order. Continual discharges of lightning followed by thunder, impart to it the character of a thunder-cloud; and the more so as it is generally accompanied by a heavy shower of rain and mud, which pours down in torrents upon the surrounding neighbourhood. These electrical discharges represent on a large scale a recently-observed fact, that vapour escaping from a steam-boiler possesses highly electric properties.

124. The environs of volcanos are covered with the remains of older and more recent streams of lava, which by decomposition yield a most fertile soil, and hence a most luxuriant vegetation surrounds the bases of all volcanos. In spite of the dangerous proximity, several villages have been built near Mount Vesuvius within the reach of its destructive activity. Moreover, in the neighbourhood of volcanos minerals are now in daily progress of formation, either crystallizing from the glowing mass, or being formed by the decomposing influence of the rising acid vapours upon other rocks. Hence in these localities a large number of minerals is to be found.

In course of time, however, all volcanos seem to become extinct, as is the case already with many. Thus, for instance, the so-called Eifel, between the river Aar and Treves, consists of a group of volcanic elevations. Lake of Laach, near Andernach, is the crater of an extinct volcano, filled with water, the whole surrounding country bearing characteristic evidence of volcanic origin.

The external form of volcanos is very peculiar, and generally *conical*. They are, in fact, gigantic air or steam vesicles which have been upheaved from below, and finally elongated to an apex, at the termination of which the steam and gas broke through. But such a disruption has not taken place in every case. We find a great many conical mountains that never were active volcanos: in these cases the force acting from below was not sufficiently powerful to pierce through the crust; the glowing mass was hardened inside before reaching the surface. Indeed, we frequently find in the centre of such conical elevations, consisting of stratified rocks, a mass of Plutonic rock, particularly basalt.

125. In Europe there are no active volcanos of importance, with the exception of Mount Vesuvius, Etna, and Stromboli, in Italy, and of those in Iceland, among which Mount Hecla is the most celebrated. The eruptions of the above-named volcanos following each other at continually greater intervals of time, though still formidable to the nearest neighbourhood, do not now extend over any considerable extent of country. History, however, records several instances of terrible volcanic disturbances, which proved destructive to entire districts, and even to whole countries. Thus in the year, A.D. 79 the flourishing and rich cities of Herculaneum and Pompeii were buried beneath volcanic ashes. Lisbon was destroyed by an earthquake in the year 1755, and even more recently most fearful instances of destruction by earthquakes have taken place in South America. In that part of the world there are entire groups of volcanos, from the position of which L.

von Buch has pointed out, that they stand on the fissures of former disruptions of the earth's crust, and have interior connection with each other. The most celebrated volcanos of America are—the *Jorulla*, in Mexico, which arose in 1758, and Cotopaxi, of the chain of Andes. The latter volcano, which is 17,662 feet in height, now and then sends forth great masses of mud and quantities of fish, thus proving in a remarkable and convincing manner its internal connection with the ocean.

126. Hitherto we have directed attention only to one of the phenomena that resulted from former revolutions of the earth, namely, the volcanos.

Let us now return to other phenomena, and consider first the development of animal and vegetable life. It is clear that organic growth could proceed in a proportionately larger scale, the longer the periods were that elapsed between the succeeding disturbances. Plants and animals made their appearance not only more plentifully but also in greater variety. Palms and coniferous plants appear in addition to ferns and equiseta, and batrachians and other amphibious animals, in addition to fishes. Intermingled with these the crustacea appeared in immense numbers. Thus the more perfect creatures followed in due order upon the imperfect, since the existence of the latter formed the indispensable condition of that of the former.

A certain change likewise took place with regard to the formation of rocks. The deposition of the insoluble and difficultly-fusible combination of silica and alumina in the primitive rocks was followed by the gradual deposition, amongst the mediæval rocks, of beds of limestone, gypsum, rock-salt, and of coal, the remains of the destroyed vegetable kingdom of earlier ages.

127. It is, therefore, natural that, in contemplating the crust of the earth a series of different strata should present themselves to us, having a peculiar and definite character according to the period at which they were formed. As in all essential points the same phenomena had occurred over the whole surface of the earth, it follows that the coeval formations of its crust must be everywhere equal or similar. Experience has, on the whole, confirmed this inference, though, in some instances, the proof is often difficult and sometimes impossible to obtain. Thus, in every locality, schistose rocks form the lowest or oldest strata. In other cases many deviations are found; for example, entire series of rocks which are met with at certain places, and entirely wanting in other localities; this is, however, after all but a local deficiency, and, therefore, of minor importance. We shall see that water was frequently the cause of the destruction of such series in some localities, while they were preserved in others.

Synopsis of Formations.

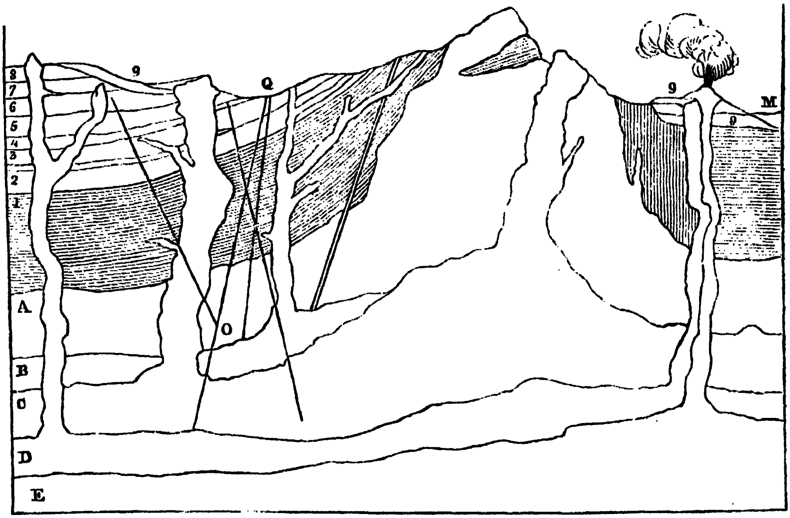
128. The term *formation* by the Geologist is applied to any portion of the earth's crust, of greater or less thickness, which arose under the same contemporary influence. Formations, which, in consequence of their close proximity, stand in mutual relation to each other, are considered by the geologist as connected *groups*. The separate layers constituting a formation are called its *members*.

129. The formations of the various Neptunic and Plutonic rocks, cannot be easily reviewed at the same time, on account of their different external and internal condition, although every aqueous formation must correspond

with a preceding igneous formation. Greenstone and porphyry which have broken through granite are as certainly of later production than granite, as greywacke and coal that overlie the slaty rocks are of more recent origin than these rocks.

It would, perhaps, be most convenient to designate the different periods of formation by those massive rocks, which were then produced, and thus to classify the entire construction of the earth's crust into the periods of the elevation of granite, of greenstone, of porphyry, and melaphyr, of basalt and of volcanos, and treating, intermediately, of the aqueous formations as they were slowly and successively deposited. In all geological systems, however, the terms have been chosen from the stratified rocks, partly because the latter were first examined scientifically, partly because the massive rocks are not everywhere defined with desirable certainty.

130. In the following Table we meet with peculiar terms, some of which are merely accidental, without particular meaning, while others indicate an essential member of the group, as, for instance, the names — keuper, (variegated marls), red sandstone (new and old), lias, fossiliferous limestone (muschelkalk), &c.



19. Illustration of the Arrangement of the various Groups of Rocks.

Stratified Rocks.

- Quaternary Rocks . { 9. Diluvial and Alluvial } Deposits.
- Tertiary . . . . 8. Molasse (comp. § 142).
- Secondary . . . . { 7. Chalk. 6. Jura. 5. Trias. 4. Zochstein. 3. Coal.
- Transition Rocks . 2. Greywacke.
- Primitive Rocks . . 1. Slate.

E. Interior mass of the earth.

Massive Rocks.

- A. Granite.
- B. Greenstone.
- C. Porphyry.
- D. Basalt.
- E. Volcanic Rocks.

M. The Sea.

O. Mineral Veins.

Systematic Arrangement of the **Formations** (beginning with the oldest).

<table>
<tr><th colspan="3">Aqueous Formations.
(Neptunic, Normal, or Stratified Formation; Stratified Rocks.)</th><th colspan="2">Igneous Formations.
(Plutonic or Volcanic, Abnormal Formation; Massive Rocks.)</th></tr>
<tr><th>Groups.</th><th>Formations.</th><th>Oldest Appellation, according to Werner.</th><th>Groups.</th><th>Most important Rocks of these Groups.</th></tr>
<tr><td>I.
Slate-Group.</td><td>Clay-slate, Mica-slate, Gneiss.</td><td>1.
Primitive Rocks.
(Urgebirge.)</td><td>A.
Granite-Group.</td><td>Granite,
Granulite,
Syenite.</td></tr>
<tr><td>II.
Greywacke-Group.</td><td>Upper and Lower Greywacke formation.</td><td>2.
Transition Rocks.</td><td rowspan="2">B.
Greenstone-Group.</td><td rowspan="2">Greenstone,
Serpentine.</td></tr>
<tr><td>III.
Carboniferous-Group.</td><td>New Red Sandstone, Coal-bed formation, Mountain-Limestone formation, Old Red Sandstone.</td><td></td></tr>
<tr><td>IV.
Zechstein-Group.</td><td>Zechstein formation.</td><td></td><td rowspan="2">C.
Porphyry-Group.</td><td rowspan="2">Felsite-porphyry,
Pitchstone-porphyry,
Melaphyr.</td></tr>
<tr><td>V.
Trias-Group.</td><td>Keuper and Fossiliferous Lime formation, Variegated Sandstone formation.</td><td>3.
Secondary or Stratified Rocks.</td></tr>
<tr><td>VI.
Jura-Group.</td><td>Jura formation, Lias formation.</td><td></td><td rowspan="2">D.
Basalt-Group.</td><td rowspan="2">Basalt,
Phonolite,
Trachyte.</td></tr>
<tr><td>VII.
Chalk-Group.</td><td>Chalk forma., Green Sand formation, Weald formation.</td><td>(2d formation.)</td></tr>
<tr><td>VIII.
Molasse-Group.</td><td>Upper Brown Coal formation, Coarse Limestone formation, Lower Brown Coal formation.</td><td>4.
Tertiary Rocks.
(3d formation.)</td><td rowspan="2">E.
Volcanic-Group.</td><td rowspan="2">Lava,
Scoria,
Volcanic Mud</td></tr>
<tr><td>IX.
Diluvial and Alluvial Groups.</td><td>Alluvial formation, Diluvial formation.</td><td>5.
Quaternary Rocks.
(4th formation.)</td></tr>
</table>

20 Configuration and Arrangement of the

Fig. 20 affords a general idea of the configuration and arrangement of the various species of rock and veins.

1. Granite.	13. Shale.
2. Gneiss.	14. Calcareous Sandstone.
3. Mica-slate.	15. Ironstone.
4. Syenite.	16. Basalt.
5. Serpentine.	17. Coal.
6. Porphyry.	18. Gypsum.
7. Granular Marble.	19. Rock Salt.
8. Chlorite Slate.	20. Chalk.
9. Quartz Rock.	21. Amygdaloid.
10. Greywacke.	A A. Primary Mountains.
11. Sandstone.	B B. Secondary Mountains.
12. Limestone.	*a a.* Veins.

131. In the study of the stratified rocks the only correct method will be to proceed from the oldest to the most recent formation; first, because this method corresponds with the progress of the development of the earth and of its productions; and, secondly, because the description of more recent conglomerates, if they contain displaced fragments of older stratified rocks, previously undescribed, could not be rendered perfectly clear.

A.—AQUEOUS FORMATIONS.

Neptunic, Normal, or Stratified Formations.

1st Group—SLATES.

Primitive Rocks.

132. The slate-group has been given in the table of classification § 130 amongst the aqueous formations, although, from the way in which it originated, we ought to class it amongst the igneous formations. In that case it ought to precede the granite-group. We class the slates among the stratified rocks because they were designated in §115 as the *first solid layer* or crust of the once entirely fluid globe, which was however soon broken through by granite. Hence the slate rocks ought to be met with everywhere, if immense masses of the stratified formations had not covered them. They are, however, distributed over the whole surface of the earth, and constitute the principal part of a great number of mountains.

Other massive rocks frequently penetrate through the rocks of the slate-group, especially greenstone, porphyry, and granite. We also frequently find in them veins of ore.

The three principal rocks of this group are clay-slate, mica-slate, and gneiss.

Clay-slate (§ 84), of which the common roofing slate is the purest kind, occurs in great variety. It is not so rich in mineral veins, and is less generally distributed than the two other rocks. Great masses of it occur in Wales, in Cumberland, about Loch Lomond, in Scotland, and in many parts of Germany.

133. *Mica-slate* (§ 85) is very important from the mighty masses in which it occurs. It forms large mountains with projecting ridges or jagged summits and precipitous ravines. A great part of the *Swiss* and *Tyrolese* Alps

consists of this rock, which is moreover the prevailing constituent of the *Sudets*, the *Riesen-*, *Erze-*, and *Fichtel-Gebirge.* It is very abundant in Scot-

21. Mountains of Mica-slate and Granite, Glen Sannox, Island of Arran.

land in the mountains that extend from Argyllshire towards Aberdeen. In the neighbourhood of the places where granite and porphyry break through it, it generally contains rich veins of ore, which lead to important mining operations.

22. Contorted Mica-Slate, Island of Arran.

Gneiss, which holds an intermediate position between mica-slate and granite, occurs in a great variety of forms, and is rich in mineral veins, particularly where it is penetrated by porphyry. This rock is widely distributed, and forms entire mountains in many parts of the continent of Europe, espe-

cially in the alpine districts, where it is commonly associated with granite. It is also abundant in Scotland.

2D GROUP—GREYWACKE.

Transition Rocks.

134. The term transition rocks, applied to this group, shows, that we have arrived at the confines of the decidedly-stratified formations. These rocks exhibit, in fact, the character of the first crust of the earth, which we have, in § 118, designated as primitive rocks.

The most important members of this group are *greywacke-slate* and *greywacke-sandstone*, which are associated, particularly in the upper parts, with masses of limestone and dolomite. The name of this group is derived from a species of finely-grained gray-coloured sandstone, of which detached and compact pieces called "Wacken" are found in Germany lying about on the fields.

Greywacke has been found distributed in large masses through various parts of Europe, especially in the interior of Bohemia and in the Tyrolese Alps. It occurs likewise in several other quarters of the globe. It is abundant in the south of Scotland at Leadhills. The valleys of the greywacke-group are mostly very winding, as, for instance, those of the Mosel and of the Aar.

The *greywacke-slates* constitute a part of the slaty mountains of the Rhine, and pass, in some places, into common slate, which is fit for roofing. This formation contains, especially in England, *Anthracite* (§ 30), a coal which is difficultly combustible and consequently little used. It possesses a perfect mineral appearance.

In many places fossils are found abundantly in the upper members of this group, while the lower contain but few of them. They are chiefly Polypi, Mollusca, and the so-called *Trilobites*, which are the remains of extinct crustaceous animals, resembling the wood louse. Fishes and plants appear here more rarely.

3D GROUP—COAL FORMATION.

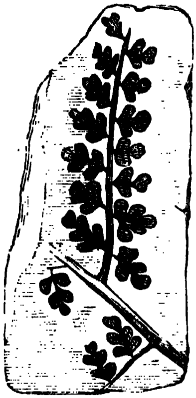
135. We have now to consider one of the most important of the various formations, since it includes coal as its essential member, a mineral which, as fuel, has become indispensable to man for domestic and industrial purposes. This group begins with a coarse conglomerate, consisting of the fragments of older rocks, and never containing basalt, limestone, or flints, and which, on account of its peculiar colour, is called *Lower New Red Sandstone* (Rothliegendes). This attains to the thickness of even 3,000 feet, and occurs sometimes on the flanks of high mountains, and sometimes constituting by itself mountainous masses, as in the Thuringian forest and the Hartz mountains. Very few impressions of plants are found in this rock.

Upon this lower new red sandstone follows the *coal formation*. It consists of beds of coal from a few inches to 20 feet (and rarely more than 40 feet) in thickness, and frequently alternating with a peculiar *grey sandstone* or dark clay-slate (schieferthon). In this order from 8 to 120 or more beds of coal frequently overlie each other, of which, however, only the thicker ones

repay the trouble of working. Beneath the coal lies the *greywacke* of the preceding group.

The outcropping of the coal formation at the surface of the earth occurs almost entirely in hilly districts; in extensive plains it is rarely found, or the beds are too far below the surface to be discoverable or even to be reached by boring.

Coal appears not to have been formed equally in all places during the period in which it originated. The remains of plants found in this stratum lead us to infer, that, during that period there existed an exceedingly vigorous and crowded vegetation, consisting principally of tree ferns and equisetaceæ, of which the *Sphenopteris Hœninghausii* (fig. 23), *Pecopteris aquilina* (fig. 24), and *Neuropteris Loshii* (fig. 25), are amongst the most beautiful that have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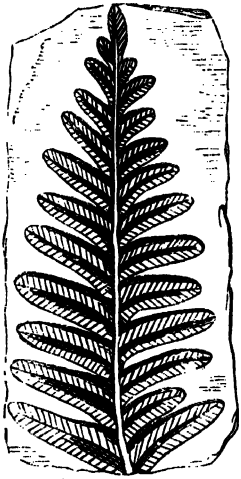

24.


25.

yet been discovered. These remarkable plants must have presented an aspect essentially different from that of our present forests. It is probable that vegetation was not everywhere equally vigorous and dense to give rise by its destruction to beds of coal. Hence it is very possible, nay, even probable, that, in some localities, the other members of this group may be found in succession without any beds of coal between them.

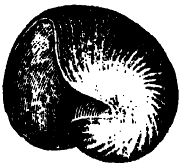
It has been generally observed, that the beds of coal are partially enclosed by hills, as in a sort of trough, similar to the position of the molasse (§ 142), from which it would appear, that vegetation was particularly luxuriant only within these mountain gorges, and could only have formed considerable deposits of coal at such places. The preceding statements afford indications to guide us in searching for coal wherever we may suspect its presence. If the part of the country be composed of primitive mountains or of Plutonic rocks, which we have designated in fig. 19, under letters A to E, we may, with certainty, conclude that coal is absent. If stratified formations of great thickness be present, it is not likely that we shall find

coal at an accessible depth; we may, however, probably find it where the aqueous formations, bordering upon the massive rocks, have been elevated and uplifted by these, in such a manner that the lower strata approach the surface or even become exposed to our view.

Our search after coal is encouraged by the presence of red sandstone aud greywacke, because these formations generally border on beds of coal. If, moreover, the surrounding hills of massive rock should form a basin, the hope of finding coal is all the more well founded, and repeated boring should be resorted to.

136. The coal-beds of Germany are not very numerous, nor is the coal of the best quality. It is in Great Britain that the best coal is most abundantly found, particularly in the neighbourhood of Newcastle-on-Tyne, in Staffordshire, and in Lanarkshire. Coal is also met with in Belgium and the neighbouring parts of France, and at Dombrowa, in Poland. The members of the coal-group have been found generally spread over America, Asia, and even Australia. In South America coal was discovered by Humboldt at a height of 8,000 feet above the level of the sea. The total amount of coal raised annually in Europe exceeds 700 millions of cwts., of which England alone contributes about 450, and Germany about 40 millions.

The *mountain limestone*, which accompanies the coal formation, is a mineral of considerable importance. It usually includes extensive metallic deposits. This is the case in Belgium, in Derbyshire, and in Scotland. Near Glasgow, it is accompanied, not only by coal, but by immense masses of clay ironstone, and in the smelting of iron from that ore, the carboniferous limestone is used as a flux. It forms very beautiful dark-coloured marbles which admit of a fine polish. Organic remains are very abundant in it, of which the following may be cited as characteristic specimens:—



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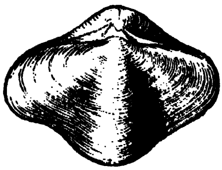

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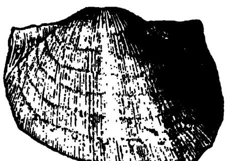

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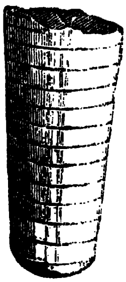


29.

26. Bellerophon costatus.
27. Spirifer glaber.
28. Productus Martini.
29. Orthoceras lateralis.

4th Group—ZECHSTEIN.

137. Of all the strata constituting the crust of the earth, that of Zechstein has been found up to the present time the least distributed. In the north-east of Germany, and especially in the county of Mansfeld, in Saxony, between the sandstone of the preceding group and the conglomerate of the following, there lies, sharply defined, this group, the most essential member of which is

a dark bituminous marl-slate rich in copper ores, whence it has received the name of *Copper-Slate.* It is worked extensively for copper. The Zechstein-group contains but few species of fossils; but these few occur in great quantities: they are all of marine origin, and consist of corals, shells, and fish.

The upper members of the Zechstein formation occasionally contain *gypsum,* which occurs in some localities in considerable masses, as, for instance, on the south of the Hartz mountains. It is often also accompanied by *rock-salt.* The salt-works of Northern Germany depend, therefore, upon the produce of the Zechstein formation. In the neighbourhood of Eisleben and Eisenach many caverns are found within the gypsum beds, which probably arose from the previous existence of rock-salt in them, which, in course of time, was washed out by the action of water.

5th Group—TRIAS.

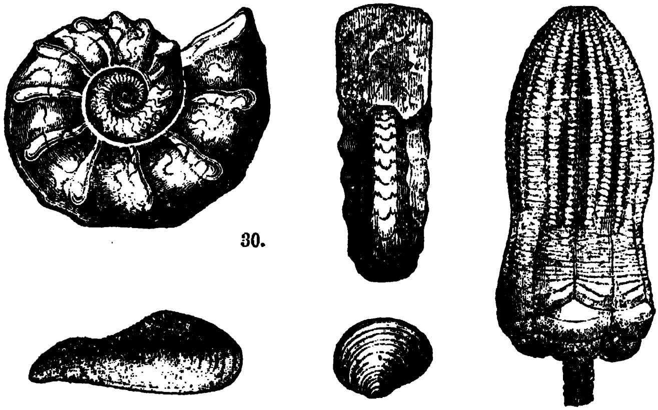
138. The name of this group is derived from the fact of its consisting of three members. They occur in Thuringia and Swabia; the entire Black Forest belongs to it, as well as the opposite Vosges Mountains, between which the Rhine has excavated its vast bed.

Gypsum and *Rock-salt* are characteristic of this group, the upper part of which, called *Keuper*, contains them in great abundance. Thus in Würtemberg all the salt-works are supplied from it, as, for instance, those at Halle, Frederichshall, Dürrheim, Wimpfen, &c.

Another member of this group is *Muschelkalk*, or fossiliferous limestone, which has received its name from the great quantities of shells it contains in separate layers.

The lowest and most abundant member of this group is the *Variegated Sandstone,* (bunter sandstein), which is of a red, yellow, or white colour, and is very abundantly distributed over the continent of Europe. The thickness of its beds varies from 400 to 600 feet, and occasionally reaches to 1,000 feet.

The decrease of fossils in the trias-group is very remarkable. The keuper



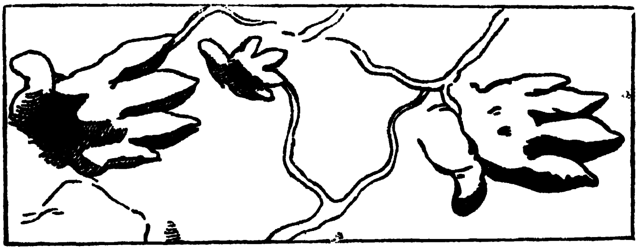
30. 31. 32. 33.

Fossils of the Trias-Group.

30. Ammonites nodosus.	32. Possidonia minuta.
31. Avicula socialis.	33. Encrinites moniliformis.

and the variegated sandstone are especially poor in these remains. They are numerous in the fossiliferous limestone (muschelkalk), but less rich in species than in Jura. Bivalve shells predominate, and the ammonites and belemnites, so frequent in the latter, are entirely wanting. We must mention, however, the *ceratites*, as belonging *exclusively* to fossiliferous limestone. Of fossil plants we find ferns, and the various species of equisetaceæ, in all the members of this group, down to the variegated sandstone. Remains of fish and amphibious animals are rarely met with.

In certain layers of the variegated sandstone there have been discovered hardened footprints, of which it is doubtful whether they belong to mammalia, to birds, or to amphibious animals, the latter being the most probable. At Hessberge, near Hildberghausen, in Saxony, unmistakeable impressions of the feet of quadrupeds have been discovered in the grey sandstone of that neighbourhood. (See fig. 34.)

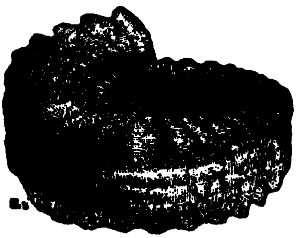


34.

6TH GROUP—JURA.

139. The Jura mountains, which rise from 4,000 to 5,000 feet, have given the name to this formation, which has been found pretty abundantly distributed all over Europe. Limestone is its principal member, which occurs alternately with dolomite, marl, clay, and sandstone. In the upper strata a lighter-coloured limestone prevails, which turns white when exposed to the air, and contains corals, while among the lower strata dark-coloured limestones and marls predominate.

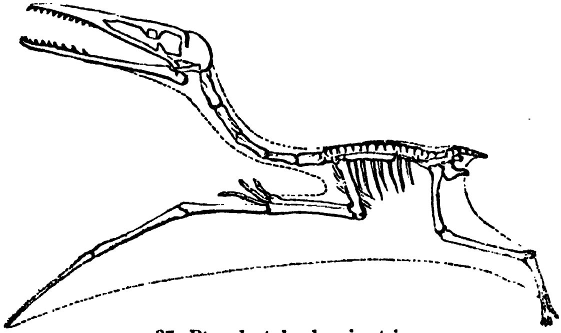
In Germany, the Swabian Alps, extending through Bavaria and Franconia up to Saxony, belong chiefly to the Jura-group. This formation is famous for its numerous caverns, containing deposits of bones. It also contains those compact tabular limestones which are important in their application as *lithographic* stones. These are found at Solenholfen in Pappenheim.



35. Ammonites Bucklandi.

36. Belemnites mucronatus.

The lowest member of the Jura-formation has received its name, *lias*, from the corruption of the word layers.



37. Pterodactylus longirostris.

Fossils are exceedingly plentiful throughout the entire formation, particularly mollusca, amongst which there are many cephalopoda, both *Ammonites* (fig. 35) and *Belemnites* (fig. 36), vertebrate fish, and saurians; of which the winged lizard (*Pterodactylus*, fig. 37) is perhaps the most remarkable member. In the lower strata marine plants are found.

The soils produced from the Jura-formation are fertile, with the exception of those derived from limestone and dolomite.

7TH GROUP—CHALK.

140. While the formations of the preceding groups make their appearance in more distant localities, and particularly where the natural conditions of alluvial and diluvial action existed on a more or less grand scale, we find the members of the cretaceous group much more independently and continuously distributed. It consists of a defined series of Lime-, Marl-, Sand-, and Clay-Strata, the uppermost of which contain the remains of marine animals, and the lowermost those of land plants and fresh-water animals.

Chalk includes a series of groups, to which the Zechstein, Trias, and Jura-groups belong, and which Werner designated as *Secondary* mountain formation. The most striking characteristic of the secondary mountain formation is the absence of the fossil remains of birds and mammalia, which indicates that it originated under physical conditions essentially different from those of the present time.

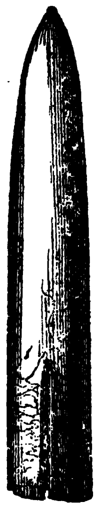
The Chalk-group has been found not only in almost all countries of Europe, but also in various parts of Asia, Africa, and America. Europe, during its formation, seems to have been almost entirely covered by the sea. The rocks of this group form a hilly, or mountainous country, but the mountains never attain to any considerable elevation.

141. The most distinguished and characteristic member of the group is *Chalk*, which attains a thickness of from 600 to 900 feet. It passes from white chalk into chalk-marl and limestone, of different degrees of hardness and purity. Chalk-soil is generally barren. In France, there are extensive plains of high and waste table-land consisting entirely of chalk.

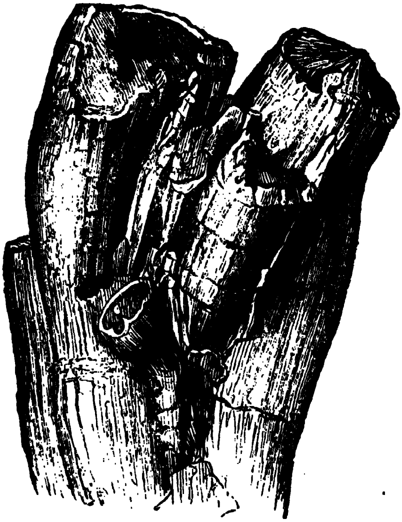
It is remarkable that *Flints* are invariably associated with chalk, in which

they are contained in the form of nodules of various sizes and shapes. A closer investigation has shown them to consist of the silicious shells of infusoria. The fossils of this group are exceedingly numerous, especially those of deep-sea animals.

Among the lower members of the chalk-group important strata of sandstone make their appearance, and are known in England as *greensand,* from being coloured by grains of green earth. In Germany it is termed Quadersandstein, on account of its splitting into large square masses. It is found particularly in Saxony, where it forms the remarkable and picturesque ravines and precipitous rocks of the district near Dresden, known as the Saxon Switzerland.



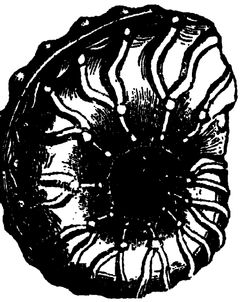
38.



39.

40.

41.



42.

FOSSILS OF THE CHALK-GROUP.

38. Belemnites mucronatus.
39. Hippurites organisans.
40. Turrilites costata.
41. Nummulitic Limestone of the Pyrenees.
42. Ammonites varians.

8TH GROUP—MOLASSE.

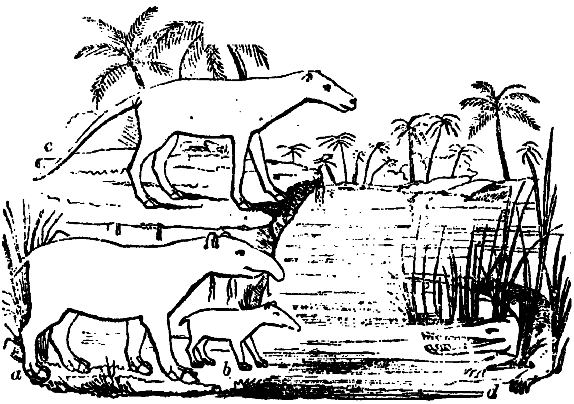
Tertiary Rocks.

142. The name of this group is derived from a coarse and loose sandstone which belongs to it, and occurs in Switzerland, where it is called Molasse: it frequently contains large fragments of other rocks, firmly cemented to a compact mass, named "*Nagelfluh*," and which rises, for instance, on the Rigi, to a height of 6,000 feet. Alternating with strata of *Brown-coal* and *Calcareous Rocks*, this group forms the margin of the Alps.

During the period when this group was formed, several large bays or gulfs of the sea seem to have been gradually filled up, in which sand, gravel, and marl, with fossils of fresh-water animals, form the principal portion of the upper strata, while in the middle strata a coarsely-grained limestone, termed *Grobkalk*, and an admixture of granular green earth, and a variety of terrestrial and marine fossils, prevail. The lower strata are composed of *Clay* and *Brown-coal*. In different localities, however, various deviations from this arrangement occur.

It is worthy of remark, that several capitals, such as London, Vienna, Mayence, and Paris, are situated in the centre of such filled-up basins. Amongst the fossils of the Mayence basin, the Dinotherium is the most remarkable which has yet been discovered. It is a gigantic animal, similar to an elephant, with two large tusks curved downwards from the lower jaw (fig. 43). In the London basin clay predominates, whilst the basin of Paris

43. Dinotherium giganteum.



44. Fauna of the Epoch of the Paris Basin.

a Palæotherium magnum. *c* Anoplotherium commune.
b Palæotherium minus. *d* Crocodile.

furnishes an excellent material for millstones. In the gypsum quarries, near Paris, a large number of marine fossils occur, amongst which about 1,400 extinct species of mollusca have been enumerated.

143. Except in Switzerland, the Molasse does not rise to any considerable altitude. In the north of Germany, in Bohemia, in the Wetterau, &c., the Brown-coal formations predominate, while the middle stratum of Grobkalk is wanting. In the place of the latter a characteristic associate of the lower section deserves our notice; it is a *Sandstone*, distinguished by its great compactness, and as being distributed in large blocks, often strikingly rounded off, over all the north of Germany.

Brown-coal occurs more frequently in flat countries and nearer the surface than in those which are at a greater altitude, where greater masses of alluvial and diluvial deposits cover it, though even there it is found sometimes uplifted to the surface by massive rocks. In the neighbourhood of Basalts the Brown-coal is considerably altered, probably from the influence of heat. Its ligneous structure almost entirely disappears, and it acquires then more the appearance of ordinary coal. (Chem. § 167.)

It has already been mentioned that well-preserved trunks of trees, leaves, fruits, and also amber enclosing insects, &c., are found in the beds of Brown-coal. Earthy Brown-coal, containing an admixture of alumina and iron pyrites, is worked for alum. (Chem. § 87.)

9TH GROUP—ALLUVIAL AND DILUVIAL DEPOSITS.

144. ALLUVIAL FORMATIONS, or depositions of soil from water, still take place every day under our own observation. Brooks and rivers continually denude from mountains and the margins of valleys more or less of their projections, according to the solidity of the rocks or soils, and the fall of the water. Thus the elevations of the earth, although imperceptibly, are nevertheless continually and permanently diminished.

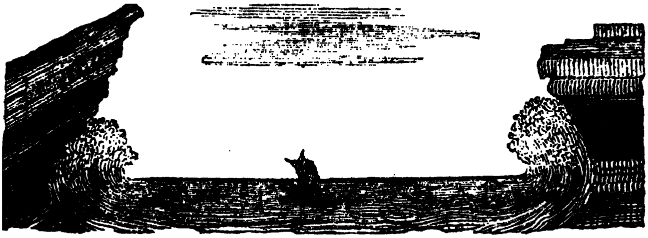
The dislodged particles are deposited again wherever the streams flow more calmly. Amongst these we find such mineral substances as were distributed through the mountainous masses, those of greater specific gravity, as gravel and pebbles, being, of course, deposited first, while fine sand and clay are carried farther on. Thus gold and precious stones, and also tin-ore, are congregated in many localities of the alluvial and diluvial formations, and may there be obtained, while to search for them in the mountains from which they are derived would scarcely pay for the cost of labour.

The greatest alluvial deposits of the mud and sand of great rivers are the so-called *Deltas*, which are triangular islands formed at the mouths of those rivers, and dividing them into many branches; as is the case with the Nile, the Rhine, and the Danube.

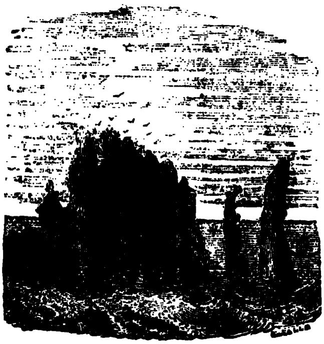
Great lakes have also been gradually filled up with alluvial deposits from the streams running into them.

The sea also continually destroys one line of coast and reconstructs another, (see figs. 45 and 46,) and in some localities the formation of a new marine sandstone or limestone has been observed going on gradually from the deposits of evaporated sea-water, and from the remains of finely-divided shells. This is the only kind of rock which has hitherto been found to contain the remains of man; a human skeleton having been discovered embedded in this rock on the island of Guadaloupe.

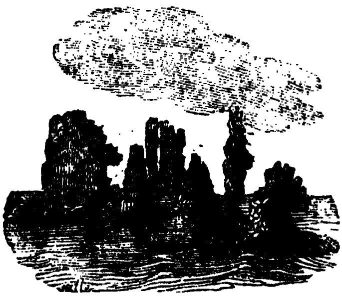
Moreover, formations of *calcareous Tufa*, of by no means inconsiderable extent, belong likewise to the present period. The carbonate of lime, which is held in solution in great quantities by the waters of many brooks, lakes, and



45. Action of the Waves on Precipitous Rocks.



46.



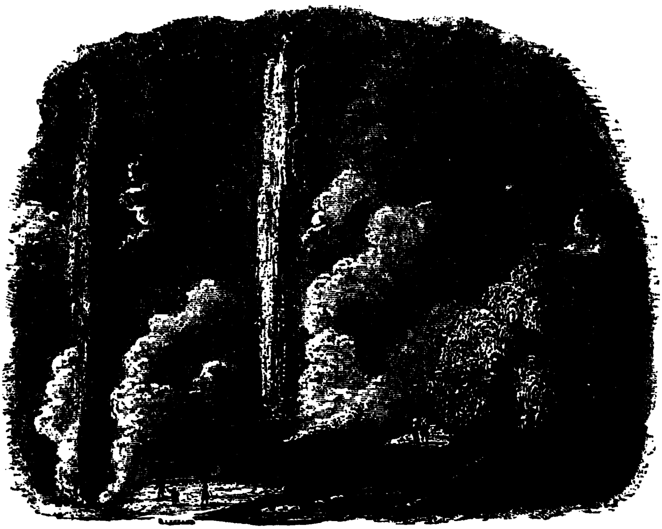
47.

Examples of Rocks worn by the Sea.

swamps, containing an excess of carbonic acid, is deposited, when a portion of the carbonic acid escapes into the air (Chemistry, § 80.) A coating of carbonate of lime is thus deposited upon all the objects in the water, a rock being gradually formed, which is at first loose and soft, but hardens by exposure to the air, and in this state forms an excellent building material. Such is the famous *Travertine* found in a swamp near San Philippo, in the neighbourhood of Rome, where a layer of this rock 30 feet in thickness has been formed within 20 years. Silicious springs, like those near Karlsbad, and the famous hot-springs of Iceland, the Geysers (fig. 48), deposit *Silicious Sinter*. Moreover, the layers of *Bog Iron-ore* (*Raseneisenerz*) deposited from chalybeate waters, and the saline crusts occurring here and there on the shores of the sea, or on the banks of lakes, marshes, and swamps, by their partially drying up, are by no means inconsiderable.

145. Of greater importance, however, are the *Turf* or *Peat Bogs*, the origin of which, being comparatively modern, has already been described in the Chemical section of this work (§ 165). They occupy the lower levels, such as the plains of Ireland, Holland, Prussia, Hanover, and Denmark. Weapons, and other objects made by man, are sometimes found deeply imbedded in these deposits of peat—for example, Celtic weapons are frequently

found in the bogs of Ireland; and on one occasion, the wooden bridge, constructed by Germanicus when penetrating through the Netherlands into



48. The Geysers of Iceland.

Germany, was brought to light. The formation of Peat may be traced back to the older period of the diluvial and molasse formations, forming there a transition into Brown-coal.

The *Beds of Infusoria* must be viewed in the same manner. The remains of an almost invisible world of the most minute infusorial animalculæ, with shells or shields around them, consisting of silicic acid, are deposited in layers, which form a friable mass of rocks, which have been described under the names of *Tripoli*, *Polishing Slate*, and *Kieselguhr*. The annexed diagram (fig. 49) represents a few of the best defined species which have been recognised by M. Ehrenberg, who has calculated that the space of a single cubic inch would contain upwards of 35,000 millions of such remains. In the ocean we find beds of corals which are built up from the bottom by Polypi, and

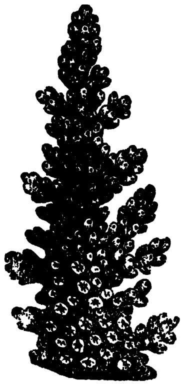
49. Infusoria.

a Desmidium apiculosum.
b Euastrum verrucosum.
c Xanthidium ramosum.
d Peridinium pyrophorum.
e Gomphomena lanceolata.
f Hemanthidium arcus.
g Pinnularia dactylus.
h Navicula viridis.
i Antinocyclus senarius.
j Pixidula prisca.
k Gallionella distans.
l Synedra ulna.
m Bacillaria vulgaris.
n Sponge spiculæ.

gradually approach the surface of the water with their calcareous ramifications, thus appearing above the surface of the sea as coral reefs, and frequently constituting coral islands (fig. 50), which abound in the Pacific Ocean.

50. Whit-Sunday Island in the Pacific.

Among the Polypi which help to form coral reefs, we may cite the following:—



51. Caryophyllea fastigiata. 52. Madrepora muricata. 53. Oculina hirtella.

Considered collectively, the alluvial formations never reach a considerable thickness above the level of the sea, and they enclose only the remains of still existing plants and animals.

146. Diluvial Formation.—This constitutes even more mighty masses than the preceding. It arose in pre-historical times as a deposit from numerous partial inundations before the existence of mankind; for it never is found to contain human skeletons or bones. We find among all nations obscure traditions of mighty floods, which, like the *Deluge*, described in the Bible, had covered a great part of the earth.

The deposits which arose from those floods are of much greater depth than those deposited from seas and rivers. They occasionally attain a thickness of 200 feet, and are generally elevated about 1,000 feet, and sometimes as much as 2,000 feet above the level of the ocean. The whole of the lower countries of Europe, as well as some plains of smaller extent in its highlands, consist of this formation. Thus the whole valley of the Rhine is filled up with diluvial deposit, which consists of a fertile marly or sandy loam, called *Löss:* being too stiff to be washed away gradually by intersecting brooks, it is removed by being first undermined, and then it breaks down vertically, or loosens in masses.

Diluvial deposits contain many remains of animals, not only of the existing kinds, but also of several extinct species. Among the latter we find particularly large terrestrial animals, such as the mammoth, the cavern bear (*Ursus spelæus*), &c. The accumulation of these fossil bones in many caverns is very remarkable; as, for instance, at Muggendorf in Bavaria, Gailenreuth in Franconia, in the Baumanns and Biels caverns of the *Hartz*, in the Nebel cavern near Tübingen, and in several other localities. The presence of these fossil bones may have arisen from the fact of those caverns having been the places of resort of various carnivorous animals, or from the action of the floods by which the bones were carried there.

147. During the period of the above-mentioned floods, the water detached and carried away (generally southward) immense masses of rock. In the great plains of Northern Germany, we find large blocks of rounded stone, principally of granite, lying about upon the diluvial deposits, and which we thence call, *Erratic Blocks* or *Boulders.* No granite can be discovered far and wide in their neighbourhood, nor at any depth below the surface. It is certain that these blocks must have been transported over sea, from Scandinavia or Finland, where mountains of the same kind of rock still exist, and they must therefore have been conveyed by immense icebergs, which deposited them on breaking up. The descriptions given by northern travellers, of the size of the icebergs still floating about in the polar regions, renders this not at all improbable.

B. IGNEOUS FORMATIONS.

Plutonic and Volcanic: Abnormal Formations. Massive Rocks.

148. In this division we have classed the groups of granite, greenstone, porphyry, basalt, and volcanic rocks, which are indicated in fig. 19, page 355, by the letters A, B, C, D, and E.

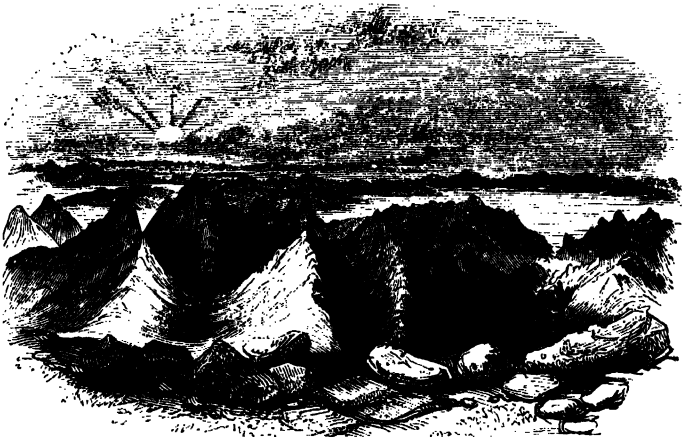
The massive rocks, not overlying each other in regular strata, but occurring only wedged, as it were, beside and into each other, it is generally very difficult accurately to separate the different groups; moreover, the fossils which so much facilitate the distinction of the stratified groups, are entirely wanting in these rocks.

Moreover, the massive rocks are distributed over the whole surface of the earth more uniformly than the sedimentary rocks, a circumstance which may be explained by supposing them to have been similarly upheaved from the interior of the earth, and formed less under the influence of external and local circumstances than the stratified formations.

A. Granite-Group.

Primitive Rocks.

149. *Granite* was long considered to be the true primitive or fundamental rock, an opinion which is generally received beyond the circle of scientific geologists. According to our previous statements, however, we consider it



54. Mountains of Granite and Mica-slate, seen from the summit of Goatfell, in the Island of Arran.

merely as the first of a series of massive rocks, which in various subsequent periods have broken through the crust of the earth.

55. Granite Boulders, Island of Arran.

This rock occurs likewise in many varieties, of which granite, granulite, and syenite, are considered by geologists as the most important.

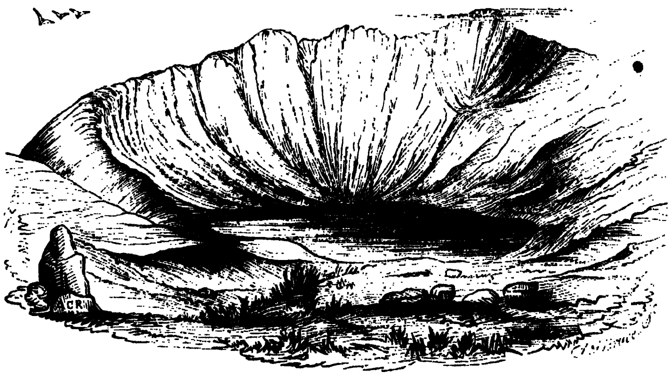
Granite (§ 87) is less distributed than the slaty rocks. It occurs principally in the form of mountains, and is rarely found in plains. The external configurations of granite are various, but peaked mountains and rugged isolated crags prevail, piled upon each other in great masses into picturesque groups of apparent ruins. Peculiarly characteristic are the large blocks, like woolsacks, which often abound on the surface of granitic districts. These are large fragments of granite, the angular edges of which having been worn off by gradual disintegration, they remain as rounded blocks. Mineral veins are not frequent in granite, but ironstone and tin-ore must be mentioned as occurring in this rock; accidental admixtures of several precious stones and laminæ of gold are likewise occasionally found.

Granite abounds in the north of Scotland, in the island of Arran, in Wales, and in Cornwall.

Granulite (§ 87) is found to a less extent, but under interesting circumstances, at the northern foot of the Erzgebirge, in Germany.

Syenite (§ 88) is found less widely distributed in Europe than granite, but is said to extend over large tracts of country in Chili, and at Mount Sinai.

Syenite is often found ruptured by granite, whence it is thought to be of earlier formation than the latter rock.



56. Corrie-an-Lachan, Island of Arran.

The above cut exhibits another remarkable peculiarity in the scenery of

granite mountains, namely, the occurrence of a lake which fills what appears to resemble a volcanic crater.*

B. Greenstone-Group.

Trap-Formation.

150. Greenstone, which differs from the rocks of the preceding group, never occurs in extensive masses, nor forms entire mountains, nor even considerable parts of mountains. It forms, on the contrary, small irregular masses, hillocks, blocks, and intricate veins or dykes, particularly in the substance of granite, slate-rocks, greywacke, and sandstone. In general, greenstone, when it appears on the surface, forms small rounded summits, which, in districts of clay-slate, may be recognised even at a distance. The internal cleavage of greenstone is chiefly either nodular or spherical, being rarely seen split in the form of columns and slabs. Of the many varieties of greenstone those of *Diorite* (§ 89) and *Serpentine* (§ 41) occur to the greatest extent. Mineral veins are rarely met with in these rocks, but they contain frequently ores, for instance, of iron, copper, and tin, as accidental admixtures, sometimes in sufficient quantities to render them worthy the attention of the miner.

C. Porphyry-Group.

151. According to Leopold v. Buch, the various porphyries must not merely be considered as a frequent cause of mountainous upheavals, since they also frequently rise up by themselves as considerable mountain masses. They have been found under the same circumstances in all parts of the globe, breaking, in trunk-like masses, or in wide-spreading veins, through the granite and slate formations, and through the greywacke and carboniferous groups of the secondary rocks. In their external appearance, the porphyries seem to be peculiarly adapted for the formation of rocky mountains, and frequently they constitute isolated hills in the midst of other rocks. They cleave into angular fragments, and frequently split into multiform

* We borrow from Professor Ramsay the following description of such a scene:—

"Before descending to the coast, let the geologist turn aside to see a solitary mountain tarn, in the silent recesses of Beina Mhorroinn. This little sheet of water is by far the most picturesque of all the lochs of Arran, and is situated deep in a hollow, called Corrie-an-Lachan. This place is perfectly lonely; not a tree is near; and except the brown heath on its margin, and a few stunted rushes by the brook, the surrounding hills are almost bare of vegetation. The water is dark and deep, and the stormy blasts of the mountain never reach its still and unruffled surface. From its edge, on all sides but that towards the sea, rise the naked hills, whose sides are either formed of massive granite blocks, which, though surely yielding to decay, yet offer a stronger resistance to the destroying influences of time than the softer portions of the mountain, where the decomposing rock may almost be seen slowly crumbling away.

"A remarkable feature of the granite hills of Arran, is the Corries (one of which is represented in the cut). These may be frequently observed in the ridge between Brodick and Sannox, and in the hills of the interior. They generally present the appearance of a volcanic crater, part of one side of which has disappeared; and the masses of granite which compose the encircling hills are frequently arranged in layers diverging from the centre of the Corrie according to the angle of inclination of the hill. For obvious reasons it will be evident to the most inexperienced observer, that there is no analogy between the Corries (Corrie = Cauldron?) and modern volcanic craters; and it is probable that they owe their origin to the softer nature and earlier decay of the rock, with which at remote periods they may even have been nearly filled. May not even the great glens owe their origin to the same cause?"—*Geology of the Island of Arran*, 8vo, Glasgow, 1841, page 50.

pillars and slabs. In their points of contact with other rocks, *Breccias* frequently occur (§ 96).

A great many varieties of porphyry exist, amongst which *pitchstone-porphyry*, *melaphyr*, and *amygdaloid*, are the most important.

Pitchstone porphyry occurs only in isolated masses. *Melaphyr* and *amygdaloid* are more widely distributed; they do not, however, constitute extensive districts, but form small trunk-like masses and irregular veins in Upper Silesia, Bohemia, Saxony, Scotland, and in many other localities.

D. Basaltic-Group.

152. Basalt is an upheaved rock of so decided a character, that it is easily recognised even by the unpractised eye. Being of much later date than most of the secondary formations, or than the above-named massive rocks, it is found to have broken through them and penetrated even up to the molasse-group. Only the diluvial and alluvial formations have been formed since the appearance of basalt.

Basaltic rocks frequently form lines of spreading hilly country, independent of chains of mountains; or what is very characteristic, they constitute single dome-shaped elevations or conical hills in the flat regions of the stratified formations. They are distributed all over the globe, and in Germany they form a very remarkable basaltic zone, running from east to west.

Isolated basaltic cones sometimes attain a height of 1,000 feet, and present to the eye the most varied and graceful cleavages; the basalt itself consisting mostly of regular hexagonal or pentagonal columns.

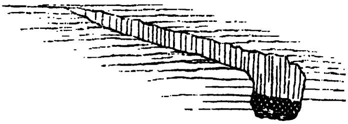
The more important varieties are *Phonolite* (§ 93) and *Trachyte* (§ 94); which are, however, rather rare, and occur mostly associated with the common basalt.

57. Basaltic Columns, Island of Arran.

The rocks of this group are not penetrated by veins of ore.

Wherever the basaltic rocks border on other kinds of rocks, the most remarkable phenomena originated at the period of their upheaval as a glow-

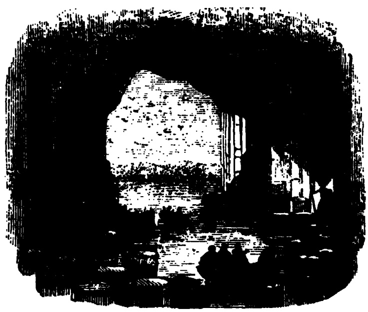
ing liquid mass. In such localities these latter rocks have undergone a great alteration which is still distinctly visible, being partly fused or reduced to mere slag, similar to the effects of volcanos, still in activity, or to the process of our smelting furnaces, where such igneous formations are constantly produced on a smaller scale. The appearance produced by the junction of the trap-rocks with sandstone, slate-rocks, &c., can be easily examined at Dunoon, in the Island of Bute, or in numerous other localities on the Clyde.



58. Sunk Trap Dyke.

59. Raised Trap Dyke.

When a trap dyke is more durable than the penetrated strata, the rock which it traverses being worn away by the action of the elements, the trap dyke is left above its surface in the form of a wall (fig. 59). But when the dyke is more perishable than the rock which it pierces, the trap decomposes and leaves a hollow, bounded on each side by a perpendicular wall of sandstone (fig. 58).



60. Fingal's Cave.

E. Volcanic-Group.

153. We have already (in § 123) described in detail the origin, the activity, and the influence of volcanos upon their surrounding neighbourhood. According to modern views, all upheaved massive rocks might be considered as extinct volcanos, some of which are of immense extent. However, it is only with the group of basalt, immediately preceding the volcanic group, that we find a considerable approximation in character to the present volcanic formations.

A characteristic feature of volcanos is the conical form of their summits, which appear somewhat isolated and sometimes in groups or chains. A further characteristic is the formation of a funnel-shaped crater at their summits. The rocks which we meet with in volcanos, and in their immediate

neighbourhood, consist of *lava*, *slags*, and *trachyte* (§ 94), in which no mineral veins are present.

61. Extinct Volcanos of Auvergne.

CONCLUSION.

154. On taking a retrospective glance at what has been stated under the heads of Mineralogy and Geology, we find ourselves progressing most remarkably from the minute and elementary to the greatest and most highly complicated phenomena.

First. Mineralogy teaches us, in the simple mineral specimen, the chemical combinations formed by Nature, the determination of which, as well as of their form of crystallisation, is properly considered a part of Chemistry. These minute crystals do not, however, occur merely isolated, but in aggregations of great numbers united into cohering masses. We also frequently find the crystals of different minerals intermingled and closely united in greater masses, when their definite form of crystallisation is often interfered with by the mechanical actions of friction, pressure, admixture, and by partial or entire fusion or solution. Thus, from the consideration of the simple and mixed minerals, Geology leads us on to the contemplation of great masses, and their arrangement and succession.

155. In describing so many most useful mineral substances, the importance of the science here treated must have become evident to the reader.

The mineralogist teaches us not only to *distinguish* such minerals as sulphate of baryta and sulphate of strontia, limestone, salt, sulphur, coal, and the best of ores, so indispensable to man, but he also informs us under what local circumstances we may expect to find them.

Besides this, the knowledge of the mineralogist enables him better to judge the nature of soils produced by disintegration; and, indeed, this knowledge of soils, so essential to agriculture, has been made a separate subject of a practical scientific treatment, founded on Mineralogy. Geology, again, has lent its aid for another important purpose,—to procure one of the most indispensable necessaries of life, viz., water. In the section *Physics* (§ 81), it has been shown that this liquid, while endeavouring to find its level, springs up as a fountain wherever it can force its way. Experience has taught us, however, that we can assist its course in this respect, that we can make channels for it in certain localities, or, in other words, that we may form artificial springs by boring.

ARTESIAN WELLS.

156. The possibility of forming such a well, which is called *Artesian*, after the department Artois, in France, where the attempt was first made, depends upon certain geological conditions, tolerably well ascertained, according to which a well-informed geologist may easily judge whether in certain localities boring is practicable and attended with a probability of success.

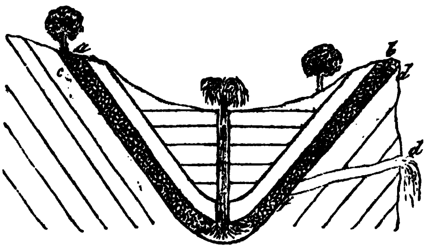
This would be the case under the following circumstances: —

(1.) Water must penetrate into the earth on an elevated point, higher than the place where the boring is to be tried.

(2.) This water must, by subterraneous channels, find its way to the place beneath the point at which the boring is made.

(3.) It must have, neither at nor below the level of the boring point, no artificial or natural issue through which can flow a quantity of water equal to that which penetrates into the earth from above.

These three general conditions may actually be fulfilled in various ways. Most commonly, however, they are realised in the stratified formations by the peculiar position and alternating character of the several strata. If, for instance, a sandy stratum, acting as a filter (*a b*, fig. 62), occupies a somewhat inclined position between two other strata impervious to water, such as clay, the water falling on the upper part at *a*, *b*, will penetrate through its whole depth, and finding no egress below on account of the basin-like form of the stratum, as in fig. 62, or from its resting at the lower termination upon a compact rock, the water will collect under sufficent pressure to form an artesian well. The overlying strata need only be bored through, as shown in the centre of the figure, to obtain the desired spring. The passage *f*, *d*, in fig. 62, explains the manner in which a natural spring *d*, may be supplied with water from a porous bed through a fissure in the rocks. Similar conditions may exist in localities where massive rocks prevail, by means of fissures and cavities, although these are of rarer occurrence, and do not admit of a decided judgment beforehand.



62.

Hence, while in some stratified formations, we may predict frequently with great certainty the success of boring for an artesian well, such an undertaking will, on the whole, be very hazardous in localities where slaty or massive rocks predominate, and the desired result would not even be at all probable.

Artesian wells from a great depth possess a high temperature, as, for instance, the water of the artesian well at Grenelle, near Paris, which is 1,663 Parisian feet (= 540 met.) in depth, possesses a temperature of 28° C. (82·4 F.) This opens up a speculative view of making the immense store of subterraneous heat available for our domestic purposes. Should the stratified formations, from which the artesian spring rises, contain mineral substances soluble in water, in such case it would appear as mineral water. Thus in

the Keuper and Zechstein (§ 137 and 138), so rich in beds of rock-salt, saline springs, for the manufacture of common salt, have been frequently found by boring.

MINING.

157. In order to procure for man the comforts and necessaries of life by the assistance of gold and silver, of iron, coal, salt, and other minerals, the MINER unceasingly performs his laborious task with unwearied perseverance. Miners are generally a poor but an honest and industrious class of people, quiet and earnest at their work, but cheerful and fond of musical entertainment in their hours of recreation. Separate manners, habits, and dress, as well as a peculiar language for everything concerning their occupation, make the miners a characteristic set of men, and singularly different from agriculturists, sailors, or townsmen.

With his tools, consisting of a pickaxe, hammer, and crowbar, and provided with a safety lamp, the miner proceeds either to work shafts vertically down into the ground, forming deep pits, or he carries out galleries in horizontal directions, and by combining these two ways he penetrates the rocks in search of ores which run through them in veins or form entire beds in separate strata, as, for instance, those of coal or rock-salt. Mines are sometimes of immense extent, some shafts having been sunk to the depth of 3,000 feet: the greatest depth, however, below the level of the sea amounts only to from 1,300 to 1,600 feet, which would make only about $\frac{1}{14800}$ of the radius of our globe (V. Humboldt's Cosmos). The galleries extend in some mines to an astonishing length, as, for example, the George-gallery in the Harz, which requires three hours to pass through, and the celebrated Christopher-gallery in Salzburgh, which is 10,500 feet long. These galleries, though mostly of a height sufficient for a man just to walk through, frequently admit of access only in a stooping or creeping position.

158. The calling of the miner, besides being very toilsome, is, next to that of the sailor, exposed to the greatest amount of danger. There are many mines, in which, out of 1,000 workpeople, an average of 7 annually loss their lives, while about 200 suffer more or less personal injury from accidents. In others, it is stated, that an average of even from 12 to 16, out of 250 persons, perish annually. Sometimes, a sudden irruption of water from below or from the sides, sometimes the fire-damp (Chem. § 54), which explodes on taking fire, or suffocating gases, especially carbonic acid gas (Chem. § 53), (choke damp), prove destructive to them. At times, also, the roof of the mine itself gives way, either from negligence in propping, or from unavoidable concussions, and buries the miners alive. This frequently happens, particularly in South America, where earthquakes are still of common occurrence. All these circumstances contributed much in former times to render the miners a particularly superstitious class of people, abounding in fictions and traditions of jealous mountain sprites, dwarfs, and hobgoblins, dwelling in the interior of the mountains, and watching over their ores and treasures which they grudge mankind, and for taking of which they assail the miner, and seek to do him harm. On the other hand, they believe in benevolent fairies and protecting spirits that aid and assist them.

The progress of science and education has, however, cleared away much of this prejudice and ignorance: the better-informed miner of the present time knows how to distinguish truth from fiction, and while trying to avoid dangers by needful precautions, he puts his trust in God, the ruler of all things.

BOTANY.

1. Botany is that branch of natural science which treats of *plants*. By plants we understand those objects of nature which, like animals, display a great diversity of organisation, and increase in size from the interior, but which differ from animals by being incapable of spontaneous movement. The simplest form, however, in which a plant appears to us, is that of a minute vesicle with very thin membranes containing a fluid, and occasionally some greenish granules. The membrane, the fluid, and the solid contents of the little plant, are different, both in their form and in their chemical composition. A still greater and more striking diversity is perceptible in a larger plant, in a tree, for instance. Here the dissimilarity in form and contents of its different parts is so striking as not to be overlooked, even by a child. If we compare with a plant a simple *mineral* (Min. § 3), for example, a crystal of quartz, we find it of uniform composition through its entire mass, and consisting only of minute particles of quartz; and in like manner we find a crystal of calc-spar to be composed only of similar minute particles. Neither by the eye nor by chemical analysis can we discover the least difference in them, as is the case when a plant is submitted to observation. There are, indeed, some minerals, granite, for example, that have the appearance of a diversity in their form, yet it is easy to perceive that these *mixed rocks* are nothing more than mixtures of simple minerals.

2. If we make a series of observations on a particular plant, under suitable circumstances, we cannot avoid perceiving the peculiar changes which it successively undergoes. In the first place, the phenomenon of the fluid contained in the above-mentioned simplest form of the plant, exhibiting *motion*, is of the utmost importance. Further, it is to be observed that the plant increases in size and weight, or *grows*, that is, it receives from the surrounding soil and atmosphere the materials necessary for this increase, and assimi-

lates or adapts them to the production and extension of the ever-varying forms, under the infinite multiplicity of which all vegetation exists. Finally, a period ensues when the plant ceases to exert this self-formative energy, yields to the power of chemical laws, decays, and is forthwith resolved into its primary elements.

Here another very remarkable fact deserves notice, viz., that the materials absorbed or inhaled by a plant during the period of its growth, are, in chemical combination, form, and qualities, altogether different from the substances which we meet with in the body of the plant. We never find in the soil the substance which communicates the green colour to the leaves; nor is the starch, which so abundantly occurs in the seeds, and sometimes also in the tuberous parts of plants, to be found in the ground where they grow. The plant, therefore, has the power of *assimilating* the materials absorbed by it; and this is true, both in respect of their chemical combination as well as of the external forms which they are made to assume.

In this respect minerals exhibit a remarkable contrast. They also possess the capability of appropriating new portions, and of increasing in size. But this can only be accomplished when the surrounding media are of the same composition as the mineral itself. For example, a crystal of calcareous spar can only enlarge itself in a liquid which contains carbonate of lime. The crystal is, however, incapable of producing, from this material, either any other form or any other chemical compound, than the one appropriate to itself; it grows without either changing its form or its substance.

3. That capability possessed by plants of increasing in size by the assimilation of heterogeneous materials, we call the *vitality of* plants; and those parts by which this assimilating process is conducted, are named the *organs of plants*. In the simpler forms of vegetable life, *i.e.*, in plants of an almost homogeneous structure, all the organs act equally in the process of assimilation. In the more highly-organised orders, the various distinct organs perform separate and independent functions in the economy of vegetation, and hence are called dissimilar organs.

The mineral has no organ—it belongs to the division of *unorganised* objects.

4. It has already been stated in § 2, that plants possess an internal vital motion. Externally, however, this is imperceptible to us. Indeed, the newly-formed organs or parts keep their place without apparent motion; and if the branches, twigs, and leaves were not moved by the wind, they might seem without vitality altogether. The roaring in the trees of a forest is the voice of the storm, not that of the woods. The plant cannot change its place relatively to other surrounding objects. It appears wherever accident or design has placed its seed, and perishes where the conditions of its life cease to be fulfilled; it has no voluntary power whatever over its existence.

It is true that many flowers open and shut their petals at certain times, that the sensitive mimosa folds its leaflets, and droops its branchlets if only touched by the softest finger; and that the stamens of certain plants exhibit remarkable phenomena of mobility. But all these appearances are produced by external causes. It was either the sun, or moisture, or a touch, which caused the motion, which without one or other of these causes would never have taken place at all.

A plant, therefore, is an organised body without external voluntary movement: and hereby it is essentially distinct from an *animal*, with which, in organisation, it is closely connected. The simplest form of the animal, as of the plant, is that of a minute vesicle or cell, containing a fluid in which are some granular substances. At this stage it could not be distinguished from the simplest plant, if it had not the faculty of voluntary movement, the power of changing its place. The animal has a locomotive power. Sometimes, indeed, it is a very limited sphere to which it is confined; yet it may change its place for another more conducive to the exigencies of its being.

5. It is sufficient for the present to have given the most general characteristics by which plants are distinguished from the other objects that, with them, compose the great kingdom of Nature. A precise and clear apprehension of their varied forms and wonderful phenomena can only be obtained by a careful analysis of the nature and structure of the subjects of the vegetable kingdom. This we will endeavour to supply in the following sections.

I. The Internal and External Structure of Plants (Anatomy and Organography).
II. Vitality of Plants (Physiology).
III. Classification of Plants (Systematic Botany).
IV. Description of Plants (Descriptive Botany).

I. THE INTERNAL AND EXTERNAL STRUCTURE OF PLANTS.

(ANATOMY AND ORGANOGRAPHY.)

6. We frequently have an opportunity of observing in water, which has for a considerable time remained stagnant, green flocculent bodies, which, to the naked eye, appear in the form of exceedingly delicate threads. When viewed through a microscope they present the appearance, however, of small globular vesicles, like pearls strung on a thread. Similar rows of beads, possessing a beautiful blue colour, and consisting partly of spherical and partly of oval vesicles, may be seen, even with the unassisted eye, and very distinctly under a weak magnifying power, when we examine the hairs which invest the stamens of *Tradescantia virginica* (Spider-wort), an ornamental plant with tripetalous violet-blue flowers, which is frequently cultivated in gardens.

Although, on a cursory view, some parts of plants have the appearance of a more or less dense, uniformly connected whole, yet by the aid of magnifying-glasses we find that such is not the case. The microscope shows, that even the compactest and hardest portions of vegetables, the woody parts, and the shells of fruits, are a combination of an infinite number of minute formations, into which they may be separated. It is true that a great diversity, both in form and magnitude, is apparent; nevertheless, accurate observation has shown that the diversity consists only in variations or modifications of a membranous cell, similar to that which constitutes the green water-plant (algæ) above-mentioned, and which has received the name of *plant-cell*, or briefly, the *cell*.

Hence, the cell is properly regarded as the *elementary* or *fundamental organ* of plants; and the knowledge of the origin, the structure, the functions, and the metamorphoses which this organ undergoes during the period of its life, constitutes the foundation of scientific Botany. The title, *compound organs*, is applied to those peculiarly-formed parts, which are present in most plants, and which have special functions assigned to them in the economy of vegetation. They are, for example, the leaves, the flowers, &c.

a. SIMPLE ORGANS OF PLANTS.

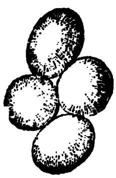
7. An infinite number of parts, selected from different plants, has been examined by the aid of the microscope, and all of these parts so examined have been found to consist of innumerable small structures, which in figure vary so considerably, that they have been distinguished by peculiar names. Further observations have, however, shown that they are all in fact but modifications of the above-mentioned elementary form, viz., the *plant-cell*, which therefore first of all claims our attention. The most important modifications or varieties of this primary organ are the *vascular* and *woody tissues*, the *cambium cells*, and *lacticiferous ducts*, or *milk-sap vessels*. In addition to these we have to investigate the *cellular tissue*, cellulose or membrane, that originates in the connection of the cells, together with the intercellular passages, interposed between the cells or vascular tissues.

THE CELLS.

8. Without entering upon the origin of the cell, a subject which has not yet been sufficiently elucidated, we find that in its developed state the cell presents the appearance of a small utricle, the form of which in the most simple case is spherical, its diameter varying from $\frac{1}{300}$th to $\frac{1}{50}$th of a line. This utricle is formed of a membrane, colourless, and of extreme tenuity: every utricle is a distinct individual, apparently incapable of further structure or extension, and without any visible *perforations*. The internal wall of the living cell is lined with a viscid, mostly yellowish-coloured fluid, which seems not unfrequently to be endowed with a peculiar motion, and which is called the *circulation* of the cell-sap. Between the cellular integument and the above-mentioned fluid, a new membranous layer is in course of time deposited, which increases the thickness of the cell. Upon this there is formed a third or even a fourth new layer; and sometimes the number of them amounts to thirty, so that the cavity in the interior of the cell almost entirely disappears. The most remarkable phenomenon connected with these formations is, that these new cellular linings are not all equally deposited upon those previously formed. Hence the tissue appears in some parts clearer or more transparent, in others darker; and, according to the mode in which the deposition has taken place, the cells appear *dotted*, or provided with *bars*, with *rings*, *spiral windings*, or *network*. The dotted cells were named *porous cells*, as long as the transparent parts of the cells were believed to be real perforations of the cellular tissue.

9. The preceding remarks have been made in reference to the interior structure of the cell; in the following observations we will confine ourselves to the consideration of its external structure and aspect. In most of the

spongy parts of plants, as in the pulp of fruits, the pith of elder, and in the examples mentioned in § 6, the cells preserve the globular or oval shape represented in fig. 1. But the cells, in consequence of that mutual pressure, more frequently assume the form of a polygon (fig. 2), the section of which is generally hexagonal. The cellular tissue may generally be compared to the bubbles produced by blowing through a straw or tobacco-pipe into soap water; or it may be illustrated by placing balls of moist clay together, and then pressing them more or less strongly together. In this manner every individual ball assumes a polygonal shape corresponding to the form of the cells represented in fig. 3; and which disposition is, in many plants, preserved with the utmost regularity. Such cells as are, with tolerable equality, extended in all directions, are named *parenchyma*, and of these are composed the tuberous parts of plants, as the potato, dahlia-roots, &c. and especially the soft spongy parts of the pith, bark, leaves, &c. We frequently, however, meet with cells which are extended longitudinally, and pointed at both extremities, as in fig. 4. The sections of these cells, which are very compactly arranged, have the appearance of a hexagon. They are termed *woody cells*, or *woody tissue* (prosenchyma), and constitute the chief portions of the more solid parts of plants, as the ligneous parts of trees, shrubs, &c. Very long, flexible cells, as those which constitute the fibres of flax and hemp, are called *bast-cells*, and appear under the microscope as round threads of uniform thickness, whereas the fibres of cotton wool, which rarely exceed one or two inches in length, when magnified, present the appearance of flattish bands with somewhat rounded margins. By these marks, the union of flax and cotton in the same web or piece of cloth may readily be detected.



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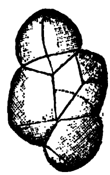

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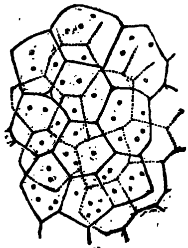

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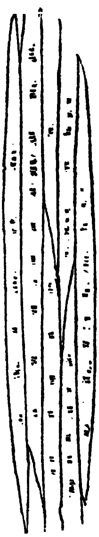


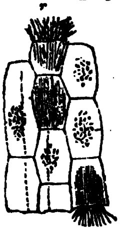
Occasionally the cells assume very abnormal shapes, as the stellate or star-formed cells. These are described as *irregular cells*.

The Contents of the Cells.

10. We very often find in the interior of the cells a colourless transparent fluid, which is called the *cellular sap*. This fluid, which consists chiefly of water, holds in solution more or less of certain soluble vegetable substances, such as gum, sugar, albumin, mucilage, acids, salts, and many other substances, which we have already, in Chemistry (§118–155), become acquainted with as the productions of the vegetable kingdom.

We still more frequently, however, meet with solid substances in the cells —as, for example, small regularly-formed crystals, which have crystallised

from the sap, or roundish granules, in which form the *starch* and *leaf-green* (Chlorophyl, p. 274), most commonly occurs, as fig. 5, in which *c* represents the cells containing chrophyl, and *r r* the Raphidian cells. In the latter cells the crystals have the appearance of bundles of fine needles, from which the name is derived (ῥαφίς, a needle). The starch is easily recognised by assuming a violet colour on the application of a solution of iodine. We also see round particles of fatty matters or of volatile oils in the cellular sap of many parts of plants; and the sap itself often appears coloured by the agency of some colouring matter which it retains in solution. Atmospheric air is likewise frequently found in the cells, especially in those which are old and contribute but little to the vital activity of the plant.



5.

In young cells we almost always meet with a *cellular nucleus* (cytoblast) in the middle of a turbid viscid liquid. This so-called cytoblast, which is intimately connected with the origin of the cell, generally disappears at a later period.

THE FUNCTIONS OF THE CELLS.

11. As every plant, whether small or great, is only an aggregate of a great number of cells, so, also, the life of a plant is nothing else but the sum of the activities of all the cells of which it is composed. The special province of the cells is to receive from the soil or atmosphere the water necessary for the various vegetative purposes, together with the nutritious materials dissolved in the watery and aerial fluids, and to circulate them through the whole body of the plant. The circulation within a plant is not carried on through the agency of tubular channels, but only by the passage of sap in all directions from one cell to another.

Since the cells have no openings, it is somewhat difficult to understand in what manner the fluid can enter into the plant from without, and by what means it can inwardly pass from cell to cell. This phenomenon, however, is dependent on the peculiar quality both of vegetable and animal membranes and fibres, viz., that they are permeable by many fluids, without being dissolved by them. Experiments show that this permeative action is carried on in accordance with definite laws. When two fluids of *unequal densities*, as, for example, an aqueous solution of sugar and mere water, are separated from each other by a diaphragm of pig's bladder, we perceive a constant tendency on both sides to restore the equilibrium in the density of the two fluids. A portion of the water penetrates the bladder, mixing with the solution, and a portion of the latter finds its way to the former by the same medium. In this experiment one important fact is to be observed, viz., that the lighter fluid always passes through the separating medium more rapidly to the denser than *vice versâ*; consequently, in this experiment more of the water passes through the bladder to the saccharine solution than of the latter to the water. This permeative capability of the tissue of vegetables and animals is called *endosmose*.

The fluid contents of the cells are always denser than the mere water which is in external contact with the roots or leaves, consequently, the latter, by *endosmose*, enters the most contiguous cells, whence it proceeds continu-

ally farther on. This operation, however, would soon restore the equilibrium between the fluid within the plant and that which is supplied from without, and thus prevent any further supply, if the fluid contents of the plant were not again rendered more dense by the evaporation of water which takes place in the leaves.

12. The cells, however, have not only to effect the circulation of the sap, as above described, through the whole plant, but also further essentially to alter the nature of the sap contained in them; so that, both in different plants and in different parts of the same plant, and even in the same parts of the same plant, at different times, we find substances essentially differing in character from each other. The cell is at the same time the source of new cells, and consequently of the entire growth of the plant. This is accomplished in two ways, either by the division of older cells, or by the formation of several new cells within the cavities of an older one. New cells are never produced between those already formed.

13. The circulation of the sap through the cells is accomplished with tolerable celerity. This may be ascertained by remarking in spring the time occupied by the sap in reaching incisions made at different heights in the stems of trees, or by observing the time which elapses during the restoration of a drooping plant, which has been placed in water for this purpose.

The force with which the cells absorb and circulate fluids may be ascertained by the following experiment. In spring let the freshly-cut end of a vine-branch be inserted into a vertical glass tube, and closely bound to it by means of a piece of bladder or caoutchouc. The water passing out from the cut surface of the branch will ascend in the glass tube even to the height of from 30 to 40 feet; and hence it is inferred that the ascent of the sap in vegetables is impelled by a force which is somewhat greater than the pressure of the atmosphere. (Phys. § 96.)

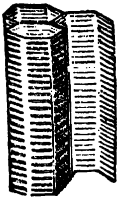
Vascular Tissue (Fibrous Tissue).

14. This somewhat inappropriate name has been derived from a form of the cells, which is never observed in very young plants, nor in any part of a plant during its development, but which is produced only subsequently by the alteration of existing cells, especially in those directions in which an active current of sap takes place. Let us imagine a series of cells superposed on each other, the walls of which disappear at the points of contact, there then arises a cylindrical tube, which is termed a *vessel* or a *vascular tissue*.

Accordingly, as these vascular organs are porous, or provided with clefts, rings, or spirals, they are distinguished by the names of *porous*, or *dotted*, *scalariform* (like steps of a ladder), fig. 6; *annular*, or *ring-formed*, fig. 7 *a*; and *spiral-formed*, fig. 7 *b*.

We have already seen in § 8 that the fibre of a cell is produced by a deposit taking place upon the originally delicate cellular membrane, in the form of a spiral band, which subsequently becomes thicker, and consequently much stronger than the membrane itself. Hence the spiral vessels were originally viewed as fibres twisted in a spiral form, and capable of being untwisted, similarly to the metallic wire which is wound round the large string of a violin. Only recently has the delicate wall of the vessel, and manner in which it is formed from the cell, been discovered. These vessels may be

easily recognised if we break gradually the stalk of a leaf, where bundles of vessels resembling the delicate threads of a spider's web will be visible at the broken ends, even to the unassisted eye. *But their true construction can only be* satisfactorily observed by the aid of a powerful microscope. In a section these vessels appear either round or hexangular (as in fig. 6).


6.

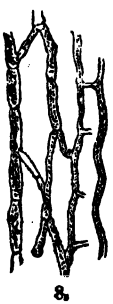

7 *a.*


7 *b.*

15. With regard to the function which the vessels perform in the life of the plant, different opinions prevail. In general, however, they contain air; and only in exceptional cases, as, for instance, in the spring, when there is a great abundance of sap, are they found to contain a fluid, hence we may justly assume that it is the cellular tissue of the wood which is the organ destined for the circulation of the sap. The subordinate importance of the vessels is evinced by the fact that many plants have no vascular organs at all, but consist only of cells, and are hence termed *cellular plants.* To these families belong the Fungi, the Algæ, the Lichenes, the Hepaticæ, the Musci * (the mushroom tribe, the sea-weeds, the lichens, liverworts, and mosses), which are the simplest objects of the vegetable kingdom both in structure and organisation. Other plants, which, in addition to cells, contain vascular tissue, are termed *vascular plants.* Hence the more perfect development of plants is dependent on the presence of vascular tissue. The vascular tissues appear single only at their first formation; they subsequently unite with new vessels, and become what are called *bundles of vascular tissue.* A union of these together, or a ramification of one from another, is never met with; nor do they ever exclusively constitute any portion of a plant; they are rather in the midst of or surrounded by the cells.

Laticiferous Cells (Milk-vessels).

16. If we tear a leaf or stalk of Celandine, Poppy, Spurge, &c., there appears on the lacerated parts a thick orange, or milk-white sap, called *latex*, of which caoutchouc always forms a constituent (Chem. § 144), and hence its clammy or viscid nature. This sap is yellowish in the Œnanthe crocata (water-hemlock or dropwort), and in a few plants it assumes a red or a blue colour.


8.

The latex is contained in tubular vessels which unite or anastomose freely, and pass through the whole plant (see fig. 8.) Their mode of development shows that they originate in the most recently-formed cellular tissue of the laticiferous plants before the existence of the spiral vessels. These passages or channels contain a fluid, colourless at first, but subsequently producing granules, and finally milky sap; and they are at first formed by the walls of the surrounding cells, but gradually a

* The latter are not entirely cellular plants; they have some vascular tissue.—Ed.

peculiar lining of remarkable tenuity is developed, which finally becomes a moderately strong membrane.

The erroneous opinion, that the latex circulates in the vegetable similarly to the circulation of the blood, has been corrected by observation. The peculiar function of this organ and its contents in the economy of the plant is not satisfactorily ascertained; only its agency seems subordinate, from the fact that in most plants it is not present.

Cellular Tissue.

17. This tissue originates in the union of the cells, and varies materially in aspect according to the prevailing form of the cells.

One sort of tissue, which derives its origin from cells of the simplest form, and which is universally found in all plants, is called *parenchyma* (see § 9). When the cells have an incompact or lax position on each other, the tissue is called imperfect, whilst in the perfect tissues the cellular walls are united to each other as completely as possible. Such expressions as elongated, regular, and tabular tissues, obviously relate to the form of the cells. The *prosenchyma* (woody-tissue), consists of thick-walled, elongated woody-cells (fig. 4).

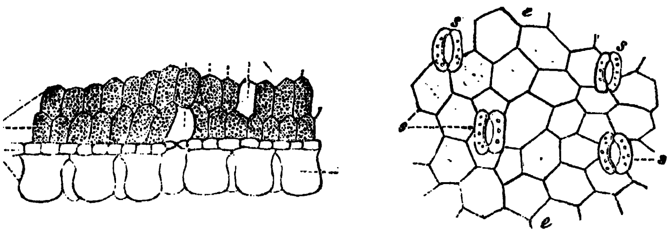
The *cambium cells* consist of a peculiar, thin-walled, and very transparent tissue. It is called *cambium* (from *cambio*, to change), because it is in this tissue that new cells are formed during the development of the plant. In the earliest stage of growth the entire plant consists of cambium, but at a subsequent period the tissue is met with only in certain places, principally between the bark and the wood.

The *bundles of vascular tissue* are a combination of the variously-formed vessels with the woody tissue, and with the cambium, and are easily distinguished from the parenchyma which surrounds them. They exhibit various peculiarities both in their arrangement and in their further development, and by these diversities large groups of plants may be readily distinguished. In one of these groups of plants, to which belongs the ferns, the bundles of vascular tissue are produced almost simultaneously. In another group, containing the palms and grasses, they receive an enlargement for a certain time; whilst finally, in a third group, containing all our forest trees, the bundles of vascular tissue continually increase while the life of the plant endures. The first kind of bundles of vascular tissue is termed *simultaneous*, the second *definite*, and the third *indefinite*.

When we consider the structure of the stem we shall have an opportunity of considering more minutely the last-mentioned kind of bundles of vascular tissue.

18. The tissue of the cuticle, or *epidermis*, which externally covers all parts of the plant while they remain green, is of a peculiar nature, and demands special consideration. It is formed of flat tabular cells, very much compressed, and in close contact, with the exception of some parts where the *stomata*, or mouths, are placed. In fig. 9 a section of a leaf is represented, the large transparent empty cells of the epidermis, and above these the parenchymatous cells of the leaf filled with greenish-coloured granules. In four places, fig. 10, stomata (*s s s s*) are seen, which have their openings surrounded by parenchymatous cells disposed in semilunar forms. Under each

stoma (mouth) there is a hollow space which is connected with the intercellular passages of the leaf. These stomata, represented below, are so numer-



10.

ous on the under side of the leaf, that hundreds have been counted in the space of a square line. Through these minute organs an intimate connection exists between the interior of the plant and the external air.

19. The epidermal cells not unfrequently exhibit very abnormal formations. When much extended in length they appear as *hairs* which are frequently branched, and in many plants they contain an irritating sap (in the nettle, for example). Bristles, prickles, glands, warts, and especially the substance which forms the well-known cork, are all due to the metamorphoses of this exterior integument.

Intercellular Canals.

20. The roundish and angular cells are never so closely arranged together as to leave no empty spaces. In lax tissues these are tolerably large, but in those which are compressed they are almost entirely invisible. These *canals* are mostly triangular, in intimate combination with each other, and are either filled with air, or with a watery fluid.

We find besides, in the stems of many plants, and especially in aquatics, between the cellular tissue, numerous and sometimes very large and regular canals which contain air. These *air-cells* or passages traverse the whole extent of the stem, and in a section of the Spanish reed (Arundo donax), and in the stem of the Water-lily, are perceptible by the naked eye.

By decay and by rupture of the cellular tissue there are frequently formed in the inside of stems *lacunæ* or hollows, which, as in grasses and umbelliferous plants, sometimes occupy the whole interior of the culm or stem.

In these empty spaces, produced by the rupture and decay of the cellular membrane, *receptacles* of various forms are found which are filled with oil, resin, gum, and other vegetable secretions.

b. COMPOUND ORGANS OF PLANTS.

21. From the consideration of the smallest and simplest organs of plants, we now proceed to the study of those which are larger and more generally known. The compound organs, according to their functions and purpose, are divided into *organs* of *nutrition* and *organs* of *increase* and *reproduction*. In our description of these organs especial attention will be paid to their external form, their internal structure, and their functions.

Organs of Nutrition.

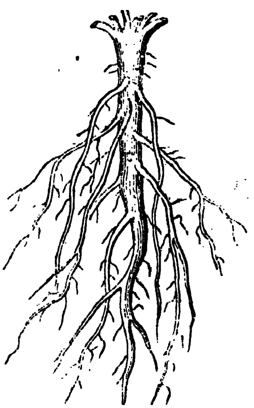
22. In the more highly-organised plants, the *root* is deemed the essential organ of nutrition, inasmuch as it supplies the plant from without with the principal part of the nourishment necessary for its growth. Besides this organ, the *stem* and *leaves* perform a more or less important part in the nutritive processes, and are also included in this section. The **stem**, so long at least as it remains in a green pulpy state, is likewise capable of receiving materials of nutrition from without, and in all states and stages is the active medium of communication between the root and the leaves. The influence of the leaves on the growth and health of the plant consists in the elaboration of the various vegetable secretions in the formation of wood, and in the absorption and exhalation of fluid and gaseous substances.

The Root, or Descending Axis.

23. With the exception of the lower families of the less highly-organised plants, some Fungi, Lichens, or Algæ, for example, which consist merely of a mass of cellular tissue without any definitie shape or arrangement, or are composed of a succession of flocculous or crustaceous *layers*, all plants have a tendency to a direction which is always perpendicular to the surface of the earth. This line of direction is called the *axis* of the plant, and is either upwards, forming the stem, or downwards, forming the root or descending axis.

The axis of every plant grows by the prolongation of both its extremities. That part of the axis which extends towards the centre of the earth is termed the *root* of the plant. The root accordingly grows in a direction from the light, and is generally in the soil. That part of the plant which grows in the opposite direction towards the light and air, is called the *stem*. The limit between the root and the stem is called the *collum* or *neck*, and when this part is distinguished by a swelling, as in the Carrot, Turnip, &c., it has received various names expressive of its form or structure.

11.



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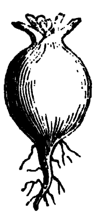


14.

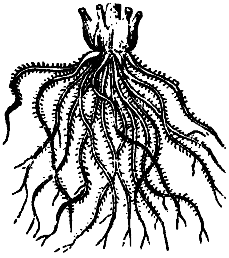
The lateral parts of plants, such as branches, that grow round about or out of the axis, are called *secondary axes* or *lateral organs.*

24. In reference to their external appearance roots are either *simple* or *compound.*

The simple root is either *entire* or *divided.* In the latter state it has a greater or less number of branches. The *tap-root* is a prolongation of the central axis or principal root which descends perpendicularly. The lateral roots are called *ramifications* of the tap-root: both forms are represented in fig. 12.

The most common forms of the root are the *fibrous* or thread-shaped root; the *cylindric,* fig. 11; the *spindle-shaped,* fig. 12; the *conical* root, fig. 13; the *globular,* or turnip-shaped, fig. 14. The *granular, tubercular,* and the *palmate* forms; the three last are exemplified by the roots of Saxifraga granulata (saxifrage), Solanum tuberosum (potato), and the last by several of the Orchids.

The compound roots originate in a multiplication of the simple roots, and are either *fibrous* or *fasciculate,* the latter owing its origin merely to the enlargement of the fibres. The accompanying fig. (15) represents the compound root with its rootlets invested with hairy appendages called *fibrils.*



15.

By far the greater number of roots penetrate the soil, still there are not a few plants which develope these organs in the water: these are called *floating* or *swimming roots.* Also many plants, particularly trees that grow in the torrid zone, develope from different parts of their stem roots instead of branches. These *aerial roots,* as they are termed, are prolonged till they reach the surface of the earth, when they strike root in the soil.* In Ivy, Dodder, and other plants of a similar nature, the roots form what are called *suckers.*

The interior structure of the root agrees in all essential characteristics with the stem, and consequently does not require a special description.

Functions of the Root.

25. Roots fix the plants, either in the soil or to other bodies or places, by some peculiar means of attachment. At all times the plant derives its prin-

* Perhaps the most remarkable instance of this kind is the banyan-tree (Ficus Indica). One of these trees, at present existing on the banks of the Nerbudda, has branches propped by adventitious stems, which spread so far as to afford a shaded space of 2,000 feet in circumference. Mr. Forbes states that the hanging roots, changed into stems in this tree, are 3,500 in number. The banyan-tree is thus beautifully alluded to by Milton, in his *Paradise Lost*:—

——————" There soon they choose
The fig-tree, not that kind for fruit renowned;
But such as at this day to Indians known,
In Malabar or Decan spreads her arms,
Branching so broad and long, that in the ground
The bended twigs take root, and daughters grow
About the mother tree a pillared shade
High over-arched, and echoing walks between."—Ed.

cipal supply of nutriment through these organs, and at certain times, viz., during the infancy of the plant, it is nourished exclusively through them. All parts of the root are capable of imbibing the water in its immediate vicinity, together with the *materials held in solution* by this fluid. Insoluble substances cannot enter into the systems of plants. The roots are chiefly developed in the direction of those places whence they derive their supply of food; thus, they accommodate themselves to the nature of the medium wherein they are developed. Sometimes they penetrate the hardest soil, and insinuate themselves into the rents and clefts of rocks in search of congenial nutriment.

The Stem.

26. We have already mentioned, in § 23, that the stem is that part of the plant-axis which grows in a direction contrary to the root, that is, towards the light and air. In many examples, however, the exterior form in nowise corresponds to our idea of a longitudinal axis perpendicular to the earth's surface. It is frequently so short as scarcely, or at all, to become visible above ground, and in this case it is distinguished by the name of *subterranean* or underground stem.

Two forms of the stem are therefore distinguished, viz., the lower underground root-like stem, which is called the *Stock* (Rhizome, or root-stock), and the elongated cylindric above-ground stem, which is the *stem-proper*. The forms of the stems comprehended in both of these principal divisions vary considerably from each other.

Forms of the *Rhizome* or *root-stock* are:—

1st. The *bulb*, a very abbreviated, orbicular, or globular stem, surrounded by thick parenchymatous leaves, which in their axils produce buds, *ex.*, the Onion.

2d. The *tuber*, an underground stem, very similar in shape to the bulb, but without a sheath, having only buds; *ex.*, the potato.

3rd. The *root-stock*, or Rhizome, is only a variety of the last or underground stem, and is distinguished from the true root by the production of buds; *ex.*, roots of Iris, &c.

Forms of the *stem-proper* are:—

1st. The stem of *mosses* is *filiform* (thread-like), leafy, sometimes simple, sometimes branched, but never attaining to any considerable size or strength.

2d. The *culm*, which we see in all grasses, is a thin, mostly hollow and usually jointed stem.

3rd. The *palm-stem*, which is peculiar to the palms and to the larger tree-ferns, mostly occurs as a simple cylindrical stem, of uniform thickness, and marked on the exterior of its circumference by the scars of the fallen-off leaves.

4th. The *stalk*, which is usually characterised by a green, herbaceous appearance; and its short duration of life, which is mostly limited to the space of one year. It is peculiar to an immense number of plants, and is susceptible of a vast variety of forms. The mode of its development, both external and internal, and the disposition of its secondary or lateral axes (branches, leaves, &c.), are of great importance in systematic and descriptive Botany.

5th. The *ligneous* or *woody-stem* is the most perfect of all the forms of this organ, and is especially distinguished by its hardness and durability. It *occurs in all our common trees and shrubs, and therefore merits special attention.*

27. In the description of the above-mentioned forms of the stem, particular attention is to be paid to some peculiarities in which the stems of different plants vary from each other. Such, for example, are the *substance, direction, situation,* and *duration* of the stem.

The solidity and strength, as well as the external aspect and internal structure of the stem, are naturally dependent on its substance, and these diversities are precisely and intelligibly indicated by the following terms:—*Solid* and *firm* or *lax*, or *soft, hollow, tubular, woody, fibrous, herbaceous, fleshy, juicy, flexible, fragile, rigid, tough, flexible, weak,* &c.

The *direction* is described as *upright, straight, procumbent, decumbent, incumbent, arched, creeping, clasping,* &c.

In reference to *situation,* the stem is either *above* or *below* the ground, *floating* or *swimming, climbing* or *clinging,* like Ivy and Dodder, *winding* to the *right* or *winding* to the *left.*

The duration of the stem is generally equal to the duration of the plant, and either survives the production of the blossoms and fruit, or perishes when this object is effected.

Hence plants are divided into, A—*annual,* or summer-plants, which are distinguished by the sign ⊙, or (1); B—*biennial* plants,—these are distinguished by the sign ♂, or ⊖ (2); C—*perennial,* are distinguished by the sign ♃ or (O-C).

Internal Structure of the Stem.

28. The inner structure of the stem is totally independent of its outward form. The diversities which we perceive in its structure are entirely attributable to the mutual relations of the cellular tissue and the bundles of vascular tissue which constitute the mass of the stems; and, above all, to the position and arrangement of the bundles of vascular tissue in reference to each other.

All plants, as we shall subsequently explain, are divided into three large groups or grand divisions called classes, which are strikingly distinguished from each other by difference in their embryos or seeds, in their blossoms, and in the interior structure of their stems. These groups are the following:—

The 1st Group comprehends the *Acotyledonous* plants, viz., such plants as have no visible blossoms nor seeds, but reproduce themselves by means of embryonic cells or spores; the bundles of vascular tissue of their stems are simultaneously produced, and are located either in the middle of the stem, or in several large masses in different parts.

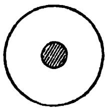
The 2d Group comprehends the *Monocotyledonous* plants, producing blossoms and seeds which germinate with only one embryonic leaf (or seed-lobe, Cotyledon). Their bundles of vascular tissue are distributed apparently without order in the cellular tissue of the stem. The nervation of their leaves is parallel.

The 3rd Group or division comprehends the *Dicotyledonous* plants, which, like the second group, produce blossoms and seeds. They develope *two*

embryonic leaves, sometimes more. The duration of the growth of their bundles of vascular tissue is unlimited, and the latter is regularly deposited on the stem in concentric layers. The nervation of their leaves is ramified and reticulated (comp. § 17).

Stem of Acotyledonous Plants.

29. To this division belong the Equisetaceæ, the Lycopodiaceæ, the *Musci* (Mosses), in which the bundles of vascular tissue occupy the centre of the



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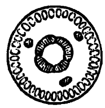


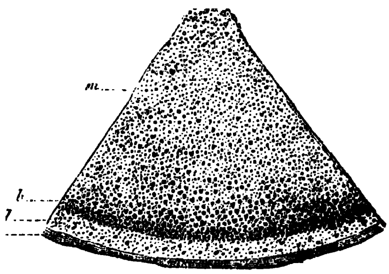
18.

stem (fig. 16); the *Filices* (Ferns), whose bundles of vascular tissue are arranged partly in large groups and partly isolated (fig. 17), and the section of which presents the appearance of certain outlines. A section of the frond of the Eagle-fern (Pteris aquilina), especially if cut obliquely and near the root, affords a moderately correct representation of a double eagle with expanded wings. Fig. 18 shows again the arrangement of the bundles of vascular tissue of another family, so that every family of the acotyledonous plant may be easily recognised by the position of the bundles of vascular tissue.

It is further to be observed, that in all acotyledonous plants the bundles of vascular tissue increase and grow only at the summit.

Stem of Monocotyledonous Plants.

30. To this class belong, among many others, the grasses, sedges, rushes, and bulbous plants. The stem of the palm, however, is best adapted for exhibiting the peculiarities by which this class is distinguished from the other two. If we examine a section of this stem, fig. 19,* we perceive a great number of separate bundles of vascular tissue dispersed without order among the cellular tissue of the parenchyma. The growth of stems belonging to plants of this class is effected, not by the increase of the bundles of vascular tissue already present, but by the production of new bundles at the circumference of the stem, which extend to the summit, and hence such stems increase in length as well as in circumference.



19.

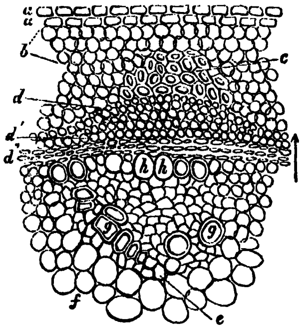
* *m* Medullary portion, *b* external woody portion, where the bundles of vascular tissue are more numerous, *l* circle of more slender fibres, *e* cellular epidermal portion.

STEM OF DICOTYLEDONOUS PLANTS.

31. As this kind of stem is peculiar to all our common trees, and to the great majority of plants, it requires our special attention.

In all these stems the bundles of vascular tissue are regularly arranged in concentric layers around a common centre, which is formed of parenchymatous cells, and is called the *pith*. The growth of the stem not only takes place at the extremities of the vascular bundles, but also by the formation of new circles of vascular bundles at the circumference of the tree.

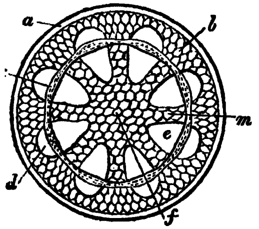
Before we, however, proceed to investigate the position of the bundles of vascular tissue in dicotyledonous stems, it is necessary that we should examine one very carefully. Fig. 20 represents a transverse section of a bundle of vascular tissue of a dicotyledonous plant, magnified 230 times. The arrow indicates the direction from within outwards. We here perceive the vascular bundle proper surrounded by a very large-celled tissue (*a a′ b e f*). The almost square cells *a a′* form the epidermis on which follows the less dense cellular tissue of the bark. The latter surrounds a half-moon-shaped bundle of bast-cells *c*, which are separated, in the direction towards the interior, by a layer of cambium *d d′ d″*, from the bundles of vascular tissue, consisting of vessels and longitudinal cells. The latter tissues may be distinguished in the transverse section by the thicker walls (*g g*) and by their greater breadth (*h h*). It is further to be remarked that the cambium (§ 17) *d d″*, appears on both sides of the bundles of vascular tissue, and extends to the next bundle, and thus presents an uninterrupted circle throughout the entire circumference of the stem.



20.

On examining the section of a one-year old dicotyledonous stem, magnified six times, as in fig. 21, we perceive several parts clearly distinguishable from each other, corresponding with the arrangement of the bundles of vascular tissue.

Enclosed by the epidermis *a* is a large-celled tissue *b f* and *m*, in which a number of vascular bundles form a circle. In each of these we notice that the outer portion, consisting of bast-cells *c*, is separated by the cambium *d* from the inner woody portion *e*. The cambium forms a closed circle which penetrates through all the vascular bundles.



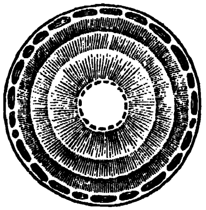
21.

In the course of the further development of the stem, the parts *a b c* constitute the *bark*, the vascular bundles *e* the *wood*, and the cellular tissue *f* its pith. The tissue *m* penetrating between the vascular bundles, are called the *medullary rays*. The cambium is to be regarded as the most important part, since it is

the source of new bundles of vascular tissue which year by year increase the circumference of the stem.

32. The growth of a dicotyledonous stem is continued by the formation of a new circle of vascular bundles on the circumference of the stem in the second year. Each new bundle, as has already been shown, is produced in the cambium, and consequently is deposited between the wood and inner bark.

Thus every year a new layer is deposited between the previous formation and the bark; and a section will exhibit these concentric rings of wood obviously distinct from each other; and as one year is requisite for the formation of a single layer of wood, these depositions are named *annual layers*



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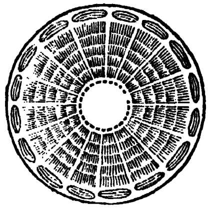


23.

or *rings*. In fig. 22 we have a representation of a stem three years old, and in fig. 23 one of five years of age.

As the cortical layers are considerably less than the woody part of the vascular bundles, and as the cellular tissue of the bark increases but little, it follows that the bark does not increase in the same ratio as the wood, and consequently the annual layers are less distinct in the bark than in the wood. The annual rings are accordingly a certain indication of the age of a tree.

The pith and medullary rays obtain little or no increase during the life of the tree; and after a considerable period has elapsed the pith is no longer visible.

The medullary rays may, however, be likewise recognised, in stems which are many years old, by the longitudinal fissility of wood being more easy in the direction in which they penetrate between the bundles of vascular tissue; the cleaved surfaces having a shining aspect which has been called the silver-grain of the timber.

33. If we cut a horizontal section from an old and sound stem, it will be seen that the external or more recent woody rings possess a less degree of hardness than the inner rings which form the internal part of the stem. The younger wood, which is called *sap-wood* or *alburnum*, may generally be distinguished from the older, which is termed by carpenters heart-wood or *duramen*, by possessing a lighter colour. The use of sap-wood is generally avoided, if possible, since it favours the propagation of fungi and rot, and because it is moreover very liable to be attacked by the wood-worm.

The difference in colour is particularly remarkable in the stem of the beech, in which the whitish alburnum forms a striking contrast with the reddish-brown heart-wood. In ebony wood the black duramen is surrounded by a well-defined layer of alburnum.

Lignification is effected by the walls of the cells which constitute the greater part of the bundles of vascular tissue, being gradually thickened by the deposition of new interior layers. In consequence of this continued deposition of new wood the cells, with the increasing age of the tree, become less adapted for the circulation of sap, and at last they dry up entirely

In the course of time the *bark* likewise undergoes essential changes. The epidermis bursts and soon entirely disappears as the branch or stem increases in circumference. "As the additions to the woody-layers on the outside and to the bast in the inside take place, there is a constant ...tion going on, by which the bark becomes compressed, the fibres are o... separated so as to form meshes, its epidermis is thrown off, and the ...phl...cum is either detached along with it or is ruptured in various ways ... give rise to the rugged appearance presented by the elm and cork-oak. In some trees the bast is very distensible, and its outer cellular covering is not much developed, so that the surface remains smooth, as in the Beech. The outer suberous layer sometimes separates with the epider...s in thin plates or scales. In the Birch these have a white and silvery aspect. There is thus a continual destruction and separation of different portions of the bark. The cellular envelope and liber may remain while the epiphlocum separates, and they also may be gradually pushed off, the parts which were at first internal becoming external." The inner bark or *bast* is separated from the vascular tissue of the stem by the cambium, and may be detached with the bark. This may be effected most easily in the spring when there is a great abundance of sap. Its tenacious properties have led to its being employed for many ornamental purposes, that of the paper mulberry-tree being used in the manufacture of Chinese paper.

From the preceding statements it will be seen that in examining a stem or branch of a tree from without inwards we meet with the following parts, arranged in the order in which they are given:—1. the *bark*, consisting of several layers; 2. the *cambium*; 3. the young wood ... *alburnum*; 4. the old wood or duramen; 5. th... pith.

FUNCTIONS OF THE STEM.

34. The stem is the medium of communication between the most remote parts of the plant, viz., the root and the leaves. Through the stem rise the fluids absorbed by the fine ramifications of the root to the buds from which are developed leaves, flowers, and fruit or young shoots. But the duty of maintaining this communication is fulfilled by the entire stem only during the first year of its existence; at a later period this function is performed almost solely by the cambium layers of the newly-formed bundles of woody tissue, and by the layer immediately under the rind. Our old hollow oaks, elms, and willows sufficiently prove this fact. In these, the whole, or almost the whole of the wood is decayed; nevertheless, they still continue to live and have a green and vigorous old age.

But let us suppose that the bark is removed, and that the sappy cambial layers are exposed to the effects of the sun and atmosphere, we shall soon perceive that these shrink, shrivel, and dry up, and are no longer in a condition to afford a passage for the sap. If the rind be removed all round about the stem, the death of the tree is the inevitable consequence. Hence

carpenters usually bark the freshly-cut willow poles about a finger's breadth, before placing them in the ground, to prevent them from taking root afresh and producing new leaves. These sap-conveying layers are, besides, the abode of the larvæ of many insects, which often devour the cambial tissues all round the tree, and thus occasion the destruction of entire woods and forests.

If, however, the tree be accidentally deprived of only a portion of its bark, and when the denuded part does not extend all round the stem, the bark may be renovated by the activity of the tissues; and this will be considerably promoted and accelerated by protecting the wounded parts from the injurious effects of solar and atmospheric influences by a plaster of clay, marl, or any adhesive compost.

Leaves.

35. The lateral developments surrounding the stem or branches, viz., organs which assume an expanded, flattened development, in contrast with the cylindrical form of the root and stem, are called *leaves*. Both air and light are necessary for their development, and they are consequently never found perfectly formed on the subterranean parts of plants.

They are distinguished by peculiar names according to their position or situation on the stem or branch. Commencing with the lowermost, we have, 1st. The *embryonic leaf* or seed-lobe (Cotyledon), which generally falls off after the development of the other leaves. 2d. The *radical* or *root-leaves*, which grow next to the root, and are generally distinguished by a form differing in some respects from the upper leaves. 3rd. The *stalk-leaves*. 4th. The *stipules*, which grow at the base of the stem-leaves in certain families of plants. 5th. The *Bracts* or *floral leaves*, which appear on the upper part of a stem or branch, and bear in the axils (axis, their angle formed by their own axis and the axis of the branch or stem on which they grow) a flower- or fruit-bud. Bracts or floral leaves are distinguished from the stem-leaves by a difference or modification of their form, and sometimes by their colour and consistence.

The leaves developed on the very extremities of a chief or lateral axis vary from other leaves so remarkably, both in shape and functions, that they receive a different name, viz., blossoms, and are described as independent organs. All the above-mentioned forms of foliage do not exist on every plant; and as the stem-leaf is the most important of these foliaceous appendages, this organ is meant when we speak simply of the *leaf*.

36. Sometimes the leaf appears at its base, *i. e.* the place nearest its point of attachment, as a semicircular investment of the stem, sometimes it entirely embraces the latter organ and is named a *sheathing leaf*. We find examples of this in the family of grasses, the leaves of which are all furnished with sheaths enveloping part of the stem. The leaf in general is connected by its base with the stem or branch through the intervention of an organ called a *petiole* or leaf-stalk; and from this petiole the *lamina* (blade) or leaf-proper is developed. When the petiole is so short as scarcely to be seen, the leaf is said to be *sessile* or *sitting;* and in this latter case the leaf often forms a semicircular sheath at its base, half surrounding the stem. The angle formed between the leaf or leaf-stalk and the stem is called the *axil* of the leaf.

37. The manifold diversities and modifications of leaves, both in form and arrangement, are so manifest as to be obvious even to the most superficial observers. They not only afford characteristic marks which distinguish certain species of plants, but even whole genera and families can be certainly identified by their means alone. Therefore the student has to pay especial attention to the forms of the leaves, comparing and discriminating the similarities and dissimilarities which occur among these infinitely-numerous and extremely-diversified objects, of which only a slight sketch can be given in the present work.

In studying the leaves, special notice must be taken of the distribution of the bundles of vascular tissue which constitute the nerves, as also of their form or shape, the nature of their margins, of their points or extremities, and of the base, and, finally, of their strength, and likewise of those qualities which occur only as exceptional cases.

The bundle of vascular tissue proceeding from the stem, and constituting the more solid part of the petiole when present, forms the *venation*, or nervous system of the leaf. The nerves are easily to be distinguished from the rest of the leaf by their lighter colour and closer consistency.

The way in which they are distributed in the *lamina* or blade is twofold. In the first case they are separated at the base of the leaf-blade into several *parallel* or *curvilineal nerves*, which extend longitudinally and again unite towards the apex (extremity or point of the leaf). Examples of this peculiar nervation occur in most *monocotyledonous* plants, as Grasses, Orchids, &c. (Compare § 28.)

In the second case there is usually a *central nerve*, called the *mid-rib*, which extends to the extremity of the leaf, and sends out *ramifications* or lateral nerves. These lateral nerves are either *parallel* (pinnate-nerved), or form a sort of network over the whole blade, and are hence called *reticulate* (disposed somewhat like the meshes of a net). This mode of nervation is peculiar to *dicotyledonous* plants, and forms one of the characters by which this class is most readily distinguished.

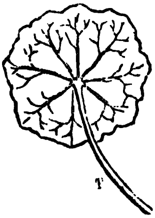
In all the forms above mentioned, the petiole and its continuations, that is, the mid-rib and the lateral nerves, are all in the same plane. There are some leaves, however, named *peltate* (like a shield or buckler), in which the leaf-nerves form an angle with the petiole. This form is exemplified by the leaf of the Castor-oil plant, &c.

Such terms as *three-*, *four-*, *five-nerved*, *palmate-nerved*, need no explanation. When the central nerve is very short, and the two lateral nerves are strong and subdivided, the nervation is called *pedate*.

Forms of Leaves.

38. The shape or form of these organs is always regulated or modified by the divergence, ramification, and greater or less extension of the divisions of the primary nerve or mid-rib, and also by the position and length of the branching lateral nerves. When the median nerve and its divisions or its branches diverge in the same plane, the leaf is flat and thin; when the divisions or the ramifications lie in different planes, or diverge in different directions, the leaf is either *orbicular* or *peltate*, or sometimes *palmate*, *digitate*, and *pedate* forms are produced (see figs. 24, 27, 28, 29,), or else succulent

leaves, like those of *Sedum acre* (see figs. 30, 31). The complete leaf consists of two parts—first, the *petiole* or leaf-stalk, which connects the flattened or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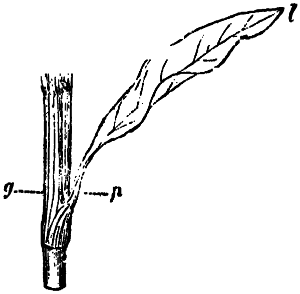

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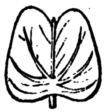
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27.

expanded portion to the stem or branch, and, second, the *lamina* or blade of the leaf (see fig. 25 *l*). The petiole is composed of the united bundles of

28.


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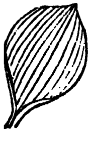
31.

vascular tissues; the blade is formed by the extension, divarication, and reticulation of the vascular bundles, the interstices being filled up with cellular tissue *(plurenchyma)*, and the whole covered by the epidermis. The petiole is not always present; and when it is absent, the leaf is *sessile* (*sedeo*, I sit). When sessile leaves embrace the stem they are called *amplexicaul* (*amplecti*, to embrace, and *caulis*, a stalk).

39. The most obvious division of leaves is into simple and compound. In the former case the blade of the leaf consists of but one piece, either entire or variously cleft or parted (see figs. 34, 35, 36, 37, 38, 39, 40). Compound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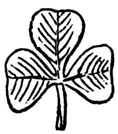
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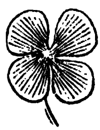
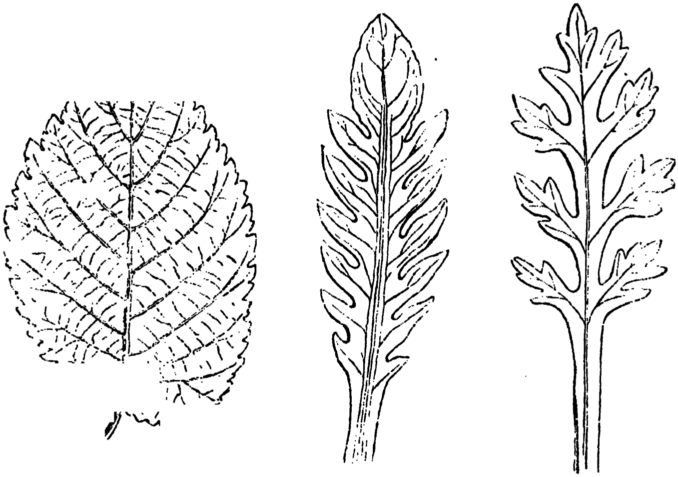

37.

leaves are composed of one or several pieces called leaflets, jointed or articulated to the common petiole (see figs. 65, 66).

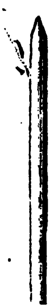
40. *Simple Leaves.*—It has already been stated that the figure of the leaf is modified by the divisions of the median or primary nerve, and by the



38. 39. 40.

divergency and length of the secondary or branching nerves. When the parenchyma is equally developed on each side of the mid-rib or leaf-stalk, the leaf is called *equal* (fig. 42), if otherwise, the leaf is *unequal* or *oblique* (fig. 38). The common and dog violets afford examples of equal leaves, Elm and Begonia of unequal or oblique leaves. When the nerves have only a very slight divergence, and proceed from the base to the apex in lines nearly parallel with the mid-rib, the leaf is *acicular*, as in the pine tribe, or *linear*, as in the grasses (fig. 47). When the divergence or the length of the secondary nerves is small, and the leaf tapers at each end, it is called *lanceolate* (*lancea*, a spear,) (fig. 50). If the middle, secondary, or branching nerves only slightly exceed in length the other lateral nerves, and if the base and apex be convex, the leaf is said to be *rounded*, *elliptical*, or *oval* (figs. 48, 54, 42); if the basal nerves be the longest, the leaf is *ovate* or egg-shaped (fig. 45); on the contrary, if the nerves at the apex be the longest, the leaf is *obovate*, or inversely egg-shaped. The *cuneate* and *spathulate* (wedge-shaped and spatula-like forms) are only modifications of this latter disposition of the nerves (see figs. 56, 41). When the nervation is prolonged downwards at an obtuse angle with the mid-rib so as to form two rounded lobes, the leaf is *cordate* or

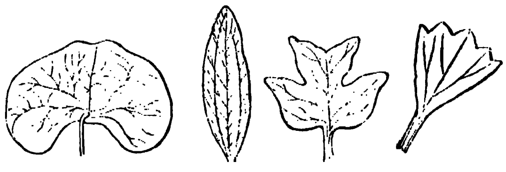
41. 42. 43. 44. 45. 46.



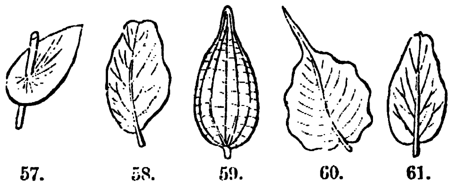
47.

heart-shaped, as in the sweet and dog violets (fig. 46); when the parenchyma is deficient at the apex, and similar rounded lobes are formed at the summit, the leaf is said to be *obcordate*, or inversely heart-shaped, as in the leaflets of white clover (fig. 36); when the base is strongly lobed, and the apex broadly rounded, the leaf is said to be *reniform*, or kidney-shaped (fig. 53); when the lobes are extended downwards and terminate in acute angles, the *sagittate* or arrow-shaped leaf is produced, as in Sagittaria sagittifolia (fig. 49). Succulent leaves are produced, as already stated, by the divergence of the nerves in different planes with a large development of cellular tissue, and their forms are usually *conical*, *prismatical*, *ensiform* (*ensis*, a sword), *acinaciform* (*acinaces*, a scimitar), or *dolabriform* (*dolabra*, a hatchet), (figs. 30, 31). When the lobes of the base are united so as to surround the stem, the leaf is *perfoliate* (fig. 57); when two leaves grow together at the base, and thus surround the stem, the leaf is *connate*, as in Honeysuckles; when the parenchyma is developed so as to fill up more than the interstitial places in the reticulation, the leaf is said to be *crisp*, *wavy*, or *curled*, as in Rheum undulatum (fig. 33), also in many species of Rumex (Dock) and Mallow; when the leaves surround the stem in a radiating manner, as in the various Galiums, the leaf is *whorled* (fig. 52); when the leaf ends abruptly in a straight margin, either at the apex or base, the leaf is *truncate* (figs. 55, 44); when the apex is only slightly notched, the leaf is called *emarginate* (fig. 26); when the depression is very slight, it is called *retuse* (*retusus*, blunt,) (fig. 58); when the point of a leaf is very long, it is called *acuminate* (fig. 60); when the point is very hard and sharp, it is called *mucronate* (*mucro*, a point,) (fig. 61).

48. 49. 50. 51. 52.



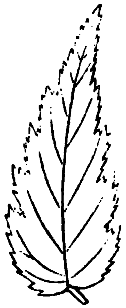
53. 54. 55. 56.



57. 58. 59. 60. 61.

41. The margin of the leaf is either entire or it is variously parted, cleft, notched, crenated, crenulate, or sinuous. When there is no projection nor incision in the margin, the leaf is called *entire* (figs. 42–46); when the margin is furnished with rounded prominences, it is either crenated or crenulate, according as the projections are greater or smaller, and the indentations of greater or less depth (fig. 60). If the projections are pointed and diverge at right angles to the mid-rib or base, the leaf is *dentate* (*dens*, a tooth,) (fig. 56). When the projections point towards the summit, the leaf

is *serrate* (*serra*, a saw). If there be two series of teeth on the margin, *i. e.* if the primary teeth are also serrated, the leaf is then *doubly serrate* (fig. 62). When the projections or prominences are far apart the margin is said to be *sinuous* or *flexuous* (figs. 63, 58, 60). If the incisions reach half-way, or nearly half-way, from the margin to the mid-rib, the leaf is said to be *cleft*, or *divided* (fig. 39), and the separated portions are called *lobes;* when the incision reaches near to the mid-rib, the leaf is *partite*, or parted (fig. 40). *Hastate*, *auriculate*, *lyrate*, and *panduriform* leaves are merely varieties of the cleft or partite leaf, the sinus or portion of the leaf not filled up with parenchyma being wider (figs. 64, 34, 35). The difference between the hastate and the auriculate leaf consists solely in the lobes of the former being horizontal, as in Rumex acetosella, in the latter these are directed towards the apex (see fig. 64). The *palmate*, *digitate*, and *pedate* forms of foliage are dependent on the number of divisions of the mid-rib or petiolary vascular bundles, and bear names indicative of the number of their lobes or partitions, as *trifid* (three-cleft), *quadrifid* (four-cleft), *quinquefid* (five-cleft), and so on (figs. 27, 28, 39). When the lobes or partitions are arranged in a winged manner, or forming angles with the mid-rib, the leaf is *pinnatifid* (*pinna*, a wing, and *findo*, I cleave,) (fig. 40); when the nervation is radiating, and not in the same plane as the petiole, the leaf may be either *orbicular*, as in *Hydrocotyle*, or *peltate* (*pelta*, a buckler), as in *Ricinus Palma Christi*, as already stated (figs. 24, 28).



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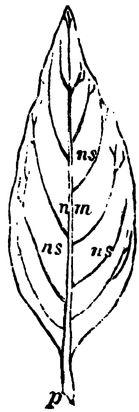

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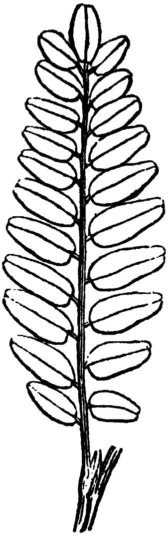
64.

42. *Compound Leaves.*—When the incisions of the leaf extend from the margin to the mid-rib, and when each portion of the compound leaf is separately jointed to the common petiole or mid-rib, such a leaf is compound, whether it consists of only one leaflet, as in Orange, or of an indefinite number, as in Acacia. When there is only one series of leaflets on each side of the mid-rib, the leaf is *simply pinnate* (*pinna*, a wing,) (fig. 65); when the leaflets or pinnæ are again subdivided, forming a secondary series of leaflets, the compound leaf is *double-* or *bi-pinnate* (fig. 66); when these secondary leaflets, or *pinnulæ*, are subdivided a third time, the leaf is *thrice-* or *tri-pinnate*, or *decompound* (fig. 67). This figure also represents a *supra-decompound* leaf, in which the subdivisions are still further extended. When the leaflets are opposite, without the intervention of a small or rudimentary leaflet, and without a terminating odd leaflet, the leaf is called *pari-pinnate*, or equally pinnate (fig. 66); when otherwise, *impari-pinnate*, or unequally pinnate (fig. 65). When the pinnæ are of different sizes, or deficient, the leaf is interruptedly pinnate (fig. 68). When all the leaflets originate in the same point of the common petiole, the leaf is *trifoliate*, *quadrifoliate*, *quinque-*

foliate, *septennate*, accordingly as the number of leaflets may be, viz., three, four, five, or seven (figs. 36, 37, 69). The compound leaf may also be



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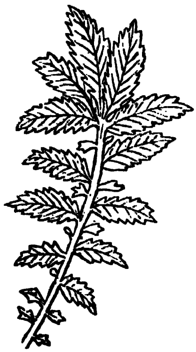

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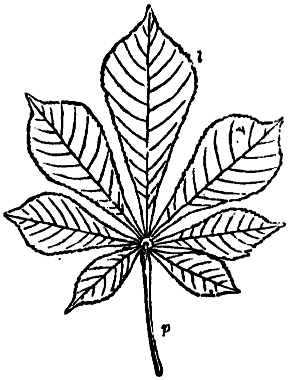

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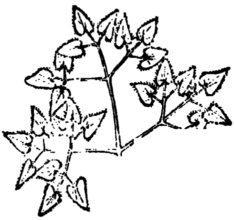


70.

bi-ternate, *tri-ternate* (fig. 70), a form abundantly illustrated by Archangel and several umbelliferous plants.

Function of Leaves.

43. The great importance of these organs in the economy of vegetation may be understood from the fact, that a tree constantly deprived of its leaves is ultimately destroyed, and that even their temporary or partial removal essentially retards its healthy development.

The function of the leaves, chiefly carried on through the stomata, described in § 18, is twofold, viz., first, the evaporation of watery fluids, and second, absorption and exhalation of different gases.

44. Plants do not assimilate the whole of the water absorbed by their roots, but exhale more than two-thirds through the medium of their leaves. The evaporation takes place through the stomata (described at page 391), of which there are on an average 300 on every square line of an ordinary leaf. The sap remaining in the cells of the leaves is thus necessarily rendered more concentrated, and according to the laws of endosmose, enumerated at page 388, the entrance of the more dilute fluids is accomplished, and consequently the circulation of sap through the entire plant is effected. The non-volatile mineral constituents which the water had absorbed from the soil remain in the cells of the leaves, and hence these latter organs when burned, yield a large proportion of ash. The copious evaporation taking place from the surface of the leaves has a sensible effect on the temperature of the atmosphere, and the effects of extensive woods, and richly-cultivated fields, upon the climate of a country is now easily understood. It has been observed that a tree of moderate size exhales, in the space of 10 hours, 15 lbs. of water, and that an acre of wheat evaporates daily 6 millions of lbs.

45. Under the influence of solar light the leaves exhale oxygen, whilst on the contrary, during the night they inhale oxygen and exhale carbonic acid. It is also true that the leaves are capable of inhaling both carbonic acid and aqueous vapour from the atmosphere for the nutrition of the plant, although this process is generally accomplished through the agency of the roots.

It only remains to be noticed, that all the functions described in this paragraph, and attributed to the agency of leaves, may be performed by any other green portions of the plant, provided that these portions be furnished with stomata.

ORGANS OF INCREASE AND REPRODUCTION.

46. If the subjects of the vegetable kingdom had not been originally endowed with a marvellous capability of continually renovating and reproducing themselves, it is very evident, from the prodigious amount of destruction effected through the various accidents to which they are liable, as well as through their incessant consumption by both man and beast, that they must long ago have vanished from the earth and have left its surface a cheerless desert. Every plant, however, is created with a reproductive power, which, in fecundity, far surpasses the most prolific of animals; and every plant, so produced, is again capable, under favourable circumstances, of producing a race of plants as numerous as that of its parent.

At first sight, these reproductive and propagative organs present such dissimilarities in the different plants, that it would seem impossible to comprise them under the same head. However, if we call to mind what has been said in § 6, in reference to the life of the cell and to its functions, the matter will appear more simple and easy.

In the case of certain plants—viz., those of the lower order which are denominated *acotyledonous* plants (see § 29)—propagation is effected by means of peculiar cells, called *germinating cells*, *embryo cells*, or *spores*, and which

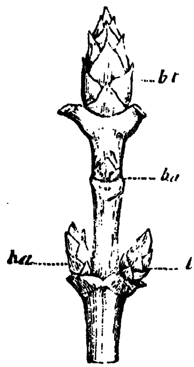
detach themselves readily from the parent plant, and, falling on the soil about, enter at once upon an independent existence of their own, and secure thus the perpetuation of the species. In all other classes of plants, the production and development of the new plant is a much more complicated affair, being dependent on the presence of certain organs of most peculiar structure, and very distinct from all other parts of the plant, viz., the *flowers*. As we shall see hereafter, there are formed in certain parts of the flower, small seminal buds, more commonly called *ovules*, and which are intended to receive the fertilising grains of the pollen, and to form afterwards the young plant or *embryo*. When the latter is fully developed and matured the ovule separates from the mother-plant, and receives now the name of *seed*. It is well known that seeds, under circumstances suitable to the exigencies of their nature, will germinate and produce perfect plants, even though they may have been lying dormant for a long time.

Finally, many parts of plants are possessed of an innate vitality of their own which enables them, under favourable circumstances, to live on, when severed from the parent stem, and to grow an independent individual of the species; the buds which we find growing on branches, leaves, tubers, and bulbs, are possessed of this faculty.

In the following paragraphs we shall investigate the nature and properties of the several forms of the bud, and those of the flower and the fruit.

The Bud.

47. The rudiments of future and more extensive development are found not only at the apex of the principal axis of a plant, but also on its circumference, and on its secondary or lateral axes. These rudimentary parts or buds present themselves in the form of shortened axes, surrounded by a cluster of closely-imbricated leaflets, the outermost of which have generally the appearance of brown scales. Such a miniature axis is named *bud* or *eye*, and is represented in fig. 71. It is called a *terminal bud* when formed on the extremity of the principal axis *(bt)*, and a *lateral bud* when it forms the apex of a branch *(ba, ba, ba)*. The buds produced on the periphery of the stem or branch are always found in the axil of previously-formed leaves, and the arrangement of the branches, like that of the leaves (see § 42), follows accordingly a definite order.



71.

The bud placed under circumstances adapted to the exigences of its nature, developes itself and forms an independent axis, the crowded and imbricated rudimentary leaflets growing gradually into leaves, placed at proper distances from each other; and, in course of time, new buds are again formed in their axils.

On a sectional examination of buds, certain differences are observed, viz., it is seen whether the future axis will produce a flower, which will terminate its growth, or whether it constitutes the rudiments of a leafy twig or

branch; in the former case it is called a *flower* or *fruit-bud*, in the latter a *leaf-bud.*

The bud may either be further developed immediately after its appearance, or its future development may be retarded for a time, during which it remains in an apparently dormant condition; as is the case, for instance, with our fruit trees, whose buds, formed during the previous summer, are not developed till the spring following. These hybernating buds are therefore covered and protected by leathery (coriaceous) scales, whereas buds that expand soon after their formation have no such protecting appendages, and present the colour of the leaves.

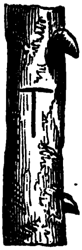
The bud contributes in various ways to the propagation of the mother plant. Either new plants spring from the buds of the lateral *shoots* or *runners*—of which mode of propagation the strawberry furnishes a familiar instance—or, the propagation is effected artificially by the process of *layering*, which is resorted to more particularly with the vine and the gilliflower, and consists in partially severing a twig growing near the ground and covering it with earth, that it may take root, or by sticking into the ground such shoots or twigs with at least *one bud.* The latter process answers more especially in the case of succulent plants, such as cactus, the oleaginous plants, and the soft-woods (willow, poplar, &c., &c.). Heat and moisture promote the growth of the roots. It is by this means that our florists provide for the propagation of nearly all our ornamental plants. All our weeping-willows are said to proceed from a green twig of that plant stuck into the ground by *Alexander Pope*, who had found it in a fig-basket coming from Smyrna.

48. Buds possess the remarkable property of developing themselves, even when severed from the mother plant, provided they be placed in a situation where they can appropriate to themselves the nutriment necessary for their growth. To this end, the bud is transferred to another kindred plant in a manner to place it in as near as possible the same relation to the latter in which it originally stood to its parent. If the operation is limited to a bud only, we call it *inoculation* or *budding*; but if a twig or scion (a *graft*) is transferred from one plant to another, we call it *grafting*. As the bud or graft transferred produces an axis or branch which possesses all the qualities of the mother plant, this practice affords an invaluable means of transferring the flowers and fruits of plants improved by cultivation to the wild varieties of the same species.

Inoculation, or Budding.

49. *Budding* is practised chiefly to improve or *ennoble* the wild stocks of the rose. The stock on which it is intended to perform the operation is transplanted into the garden, and when it has fully adapted itself to the new soil, a T-shaped incision is made in the bark down to the alburnum (see fig. 72); a bud is then removed from a cultivated rose branch along with the leaf in the axil of which it sits, and with a portion of the bark cut out in the shape of a small shield (see fig. 73); the bark at the incision in the wild stock is gently raised, the shield inserted into the slit, pushed gently downwards, and secured with bast or woollen yarn (see fig. 74); this is termed inoculation with the *shooting* eye. If the operation is performed in

spring, the stem is cut off transversely above the engrafted bud, and all the wild buds beneath are cleared away that the graft may derive the largest possible supply of nutritive matter from the stock. The engrafted bud speedily produces an axis which brings forth flowers in the same summer. If the operation is performed after mid-summer—which is termed inoculation with the *dormant* eye or bud—the removal of the stem above the engrafted bud is deferred till next spring.



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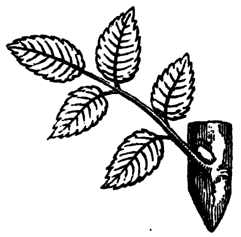
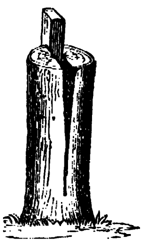


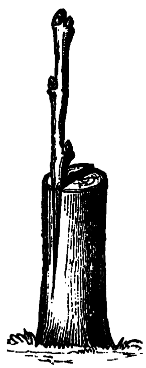
73.

74.

GRAFTING.

50. In this process a young twig, slip, or scion, with three or four buds on it, and which is called a *graft*, is transferred from one plant to another. Part of the stem of the wild stock (in the case of young plants), or part of one of the principal branches (in the case of grown trees), is sawed off transversely, and a cleft is made on the cut with a strong knife or cleaver, or with a sharp-pointed wedge (see fig. 75). The graft, cut wedge-shaped at the lower end (see fig. 76), is inserted into the slit (see fig. 77), which is then protected from light, air, and water, by stopping it up with bees' wax or clay, and tying moss or cloth round it.





75. 76. 77.

Occasionally a *cutting*, with a piece of bark attached, is inserted into the bark of a young stock, in the same way as in the process of budding (see § 49). This method of grafting has this great advantage, that, in case of failure, the stock is left uninjured; whereas miscarriage in *cleft grafting* involves almost always the decay of the stock.

In another method, which is termed *copulation*, a slip from a cultivated plant is shaped to a point at the lower end, inserted into a corresponding incision in a wild stock of equal thickness, and secured all round with bees' wax or clay, and bast or woollen yarn.

All these operations again admit of various modifications, and are performed with greater or less minuteness. The one great requisite, however, in each of them is, to effect the most intimate contact between the cut faces of the graft and stock, since this alone can secure the union of the two. The operation of grafting is performed mostly in the beginning of spring, when the circulation of the sap is most vigorous.

Affinity between the graft and the stock, as regards their sap, &c., is an indispensable condition to the success of the operations of grafting and budding; thus, for instance, roses or apricots cannot of course be engrafted on the oak tree.

The Bulb.

51. A *bulb* is a leaf-bud covered with comparatively large fleshy and succulent scales. Bulbs spring principally from subterranean stems. In certain plants, however—for instance, in the leek, and in the bulb-bearing lily—bulbs are produced also on the aërial stem, in the axil of the leaves or scales. The *bulb*, detached from the parent plant, has the power of extending its axis in the two opposite directions, thus sending forth both roots and leaves; this power it retains at least a twelvemonth, if properly protected from wet; but if bulbs are kept in a damp place, they speedily rot.

New bulbs or *cloves* are produced from the subterranean axis; after their production the parent-bulb decays, having fulfilled the purpose of its existence.

The Tuber.

52. On the *tuber* also we find buds endowed with the power of independent development; surrounded, however, not by scales as in the bulb, but by an accumulation of parenchymatous tissue, abundantly supplied with water, starch, and mucilage, and thus affording ample nutriment to the buds.

The tuber generally contains several eyes or buds, which sometimes, however, become visible only when they begin to shoot; they retain their vitality and productive power for at least a twelvemonth, if properly preserved from the rot.

The Flower.

53. Let not the botanist be blamed if, in his contemplation of the flower, he seems to feel less interest in the beauty and gracefulness of its forms, the gorgeousness of its tints, and the sweet fragrance of its odor, than in the minute details of its structure and arrangement. The attention which he bestows on these minutiæ does not lessen his appreciation of the beauties of the whole—as little as the admiration with which we view a work of art can be said to be lessened by a careful study of the means and principles of its production. It is one thing to gaze and wonder; it is another to comprehend and enjoy.

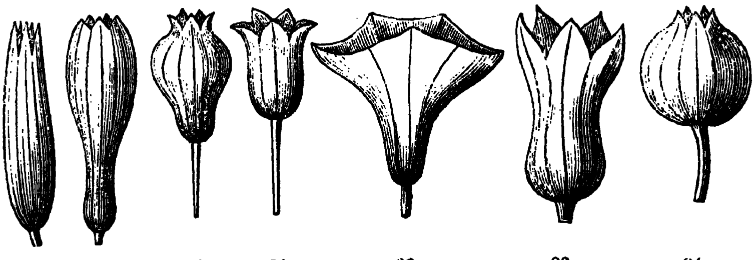
We call *flower*, the whorl of peculiarly-shaped leaves arranged on the apex of an axis of a plant, and which are intended to subserve the production of the fruit. These leaves differ essentially in form and appearance from the ordinary leaves of the plant. A perfect flower consists of four distinct rows of leaves, arranged one within the other, and which are technically called *whorls* or *verticils.* The outermost whorl is called the *calyx;* the next to it, the *corolla;* the next, the *stamens;* and the innermost whorl, the *pistil.* The two outer whorls, the *calyx* and *corolla*, are called also *floral envelopes*; they take no part in the production of the fruit, and occasionally are, one or both of them, abortive or absent, without their absence frustrating the object of

the floral functions. The two inner whorls, the *stamens* and the *pistil*, on the contrary, are indispensable for the production of the fruit; they are accordingly termed *essential organs.*

1. The Calyx.

54. The calycine leaves (*sepals, foliola, or phylla*), bear in structure and color considerable resemblance to the ordinary leaves of the plant; in many plants, however, they are colored differently; in the *fuchsia*, for instance, a fine scarlet. The calyx is sometimes *abortive*, or it falls off before the flower expands, as in poppies, in which case it is said to be *caducous*; or along with the corolla, as in ranunculus, in which case it is said to be *deciduous*. In plants where the essential organs are surrounded by *one* outer whorl only, as is the case, for instance, with the tulip, it is left undecided whether this is to be looked upon in the light of a *calyx*, or of a *corolla*, and the more comprehensive term *envelope* is applied to it. The calycine leaves either stand separate from each other, or they are laterally united to a greater or less extent; in the former case, the calyx is said to be *polysepalous* or *polyphyllous;* in the latter, *gamosepalous* or *gamophyllous, monosepalous* or *monophyllous.* In the *polysepalous* calyx we count the individual sepals and describe their form and position; in the *monosepalous* calyx the principal objects of consideration are the *shape* and the divisions at the apex, which are either single projections in the form of acute or obtuse teeth, or fissures extending about half-way down; or partitions reaching down to near the foot of the basis of the calyx. The lower part of the calyx is called the throat.

In *shape* the calyx is *tubular* or *cylindrical* (fig. 78); *clavate* or *club-shaped* (fig. 79); *turbinate* or *top-shaped* (fig. 80); *campanulate* or *bell-shaped* (fig. 81); *infundibuliform* or *funnel-shaped* (fig. 82); *urceolate* or *urn-shaped* (fig. 83); *globular* (fig. 84); *inflated*, &c.



78. 79. 80. 81. 82. 83. 84.

The *throat* of the calyx is either *naked*, or covered with *hairs*, which sometimes completely close it up.

When the sepals are of equal development and size, the calyx is termed *regular*; in the contrary case, *irregular*. A common form of the irregular monosepalous calyx is the *two-lipped* or *labiate* calyx, which is divided by a slit into two so-called *lips* or *labia*, and of which sage affords a familiar instance.

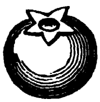
2. The Corolla.

55. The leaves of the corolla (*petals*) differ much more from the ordinary leaves of plants than the sepals do. It is in the petals that reside the gay colors and fragrant odors of flowers which form one of the principal inducements to their cultivation.

The corolla bears in many respects considerable analogy to the calyx. It is, like the latter, *regular*, or *irregular*, and its petals are, like the sepals of the calyx, either *separate*, in which case the corolla is termed *polypetalous*, or *united*, in which case it is called *monopetalous* or *gamopetalous*.

In a petal we distinguish the upper broader portion, resembling the blade of a leaf, and which is called *lamina* or *limb*, and the lower narrow portion, resembling the petiole of a leaf, and which is called the *unguis* or *claw*. These two parts may be seen very clearly in the petals of the pink.

Many of the forms of the monopetalous corolla correspond to the forms of the calyx illustrated in § 54, and are therefore designated by the same names. Among the forms of the regular monopetalous corolla we may mention here the *globular* (fig. 85), the *urceolate* or urn-shaped (fig. 86), the *campanulate* or bell-shaped (fig. 88), the *tubular* (figs. 87 and 89), the *infundibuliform* or *funnel-shaped* (fig. 90), the *hypocrateriform* or *salver-shaped* (fig. 91), the *rotate or wheel-shaped*, (fig. 92).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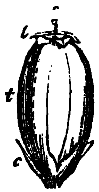

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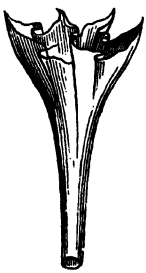
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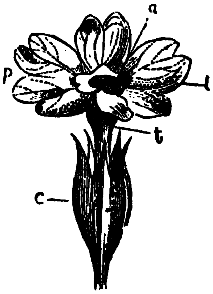
56. Of the forms of the irregular corolla, the following two—the one polypetalous, the other monopetalous—are the most common.



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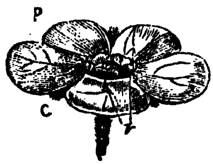
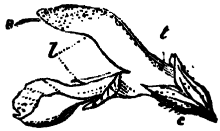


92.

93.

The *papilionaceous* corolla (fig. 93) consists of five petals; viz., one superior (or posterior), usually larger than the rest, and called the *vexillum* or *standard*; two lateral, the *alæ* or *wings;* and two inferior (or anterior), joined together to form a pointed beak called the *carina* or *keel.* This corolla is found in the pea and bean tribe, and the numerous plants which constitute the order of the *Papilionaceæ.*

In the *labiate* or *lipped* corolla (fig. 94), the limb is split into two parts, which, from a fancied resemblance to the mouth, are called *labia* or *lips.* The upper lip is sometimes strongly arched, in which case it is called *galea* or *helmet;* the lower lip is generally divided into three parts or lobes. The tubular part of the corolla is called *faux* or *throat.* When the *gap* or *hiatus* between the lips is wide and open, the corolla is said to be *ringent;* but when the throat is closed by a projection of the lower lip pressing against the upper, as in snapdragon, the corolla is said to be *personate* or *masked.*



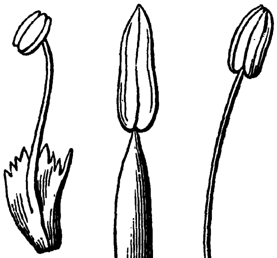
94.

The labiate corolla characterises the great and important labiate family to which belong, among others, *salvia* (sage) and *lamium* (dead nettle).

3. The Stamens.

57. The third floral whorl or verticil is constituted by the *stamens*, which, like other parts of the flower, are modified leaves resembling the leaf, or rather the petal, in structure, development, and arrangement, but greatly differing from it in shape; so much so, indeed, that one would hardly see the relation between them, were it not that the gradual transition from petals to stamens, or, *vice versâ*, from stamens to petals (in flowers becoming double by cultivation), may be clearly traced in many flowers.

If we examine, for instance, the corolla of the white water-lily, or of the pink or double rose, we find the petals gradually diminishing in size towards the centre: still farther to the centre we see them crowned with a little yellow head; those next to them are already partially *filamentous*, or thread-shaped (fig. 95); and, finally, the real stamens appear (figs. 96 and 97), which are more or less slender and elongated, and are mostly colorless.


95. 96. 97.

58. The stamen consists of two parts, a lower contracted portion, usually thread-like, and termed the *filament*, and an upper broader portion, presenting the form of an oblong or globular bag, and termed the *anther*. The latter, which contains a powdery matter, called *pollen*, is the *essential* part of the stamen. The filament is not essential to the stamen, and is often absent or abortive, in which case the anther is said to be *sessile.*

The stamens afford some of the most important characters for the classifi-

cation and description of plants; in this respect, regard is paid to their number, length, and position, and also to the circumstance, whether the filaments are free, or more or less united with each other, or with other parts of the flower. Stamens, with filaments adhering to each other, are called *adelphous* (*monadelphous*, *diadelphous*, &c.)

59. The *anther* contains the *pollen*, a powdery matter, usually yellow-colored, but sometimes also red, brown, violet, or green-colored. Pollen-grains vary from $\frac{1}{20}$ to $\frac{1}{300}$ of a line in diameter. Under a powerful microscope they appear as ellipsoidal, or sometimes spherical, triangular, polyhedral vesicles, filled with a granular semi-fluid matter (*fovilla*). To effect fecundation, the pollen-grains must come into contact with a certain part of the plant which is intended to receive them, and which is called the *ovule*, and is found in the fourth or innermost verticil of the flower, the *pistil*. Of the further development of the ovule, we shall have occasion to speak in the paragraph treating of the *seed*.

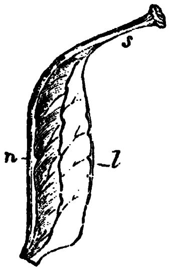
At the proper time the anther opens and discharges its contents, the pollen-grains, some of which reach the place of their destination. The position of the stamens to the pistil is usually such that the latter can readily receive the pollen-grains. In many plants, however, the stamens are too short to reach the pistils; or the two essential organs of reproduction are in separate flowers, or even on different plants. In such cases, the conveyance of the pollen from the anthers to the pistils is effected by the agency of the wind or by that of insects, and more particularly of the bee. If the anthers are removed from the flower previously to their *dehiscence* (opening), no fruit is produced.

Varieties of flowers and fruits are produced artificially, by shaking the pollen of one plant upon the flowers of another, deprived of the stamens. Many esteemed sorts of stock-gilliflowers and pinks have been produced in this way.

4. The Pistil.

60. The *pistil* constitutes the fourth and innermost whorl, and occupies accordingly the centre of the flower and the apex of the axis, whose growth is terminated with the production of the fruit.

The pistil also is formed by one or several modified leaves, called *carpels*, in this part of the flower, and which exhibit a more marked resemblance in color and structure to the ordinary leaves than the stamens and petals do. The formation of the pistil from the leaf may be considered to proceed in this manner, that the edges of the leaf are folded inwards and unite, whilst the mid-rib is prolonged upwards (fig. 98). The place where the margins of the folded leaves are united, is called *suture* or *seam* (*ventral suture*, in contradistinction to the mid-rib, which is called the *dorsal suture*); and it is here that the seed-buds or *ovules* are developed.



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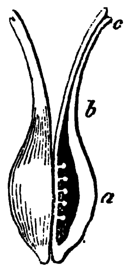


99.

The pistil consists of two parts, viz., the *ovary* or *germen*, which contains the ovules or

young seeds (fig. 99, *a*), and the *stigma* (*c*), which is either seated immediately on the ovary, in which case it is called *sessile*, or is elevated on a stalk (*b*), interposed between the ovary and stigma, and called the *style*. The stigma presents various forms; it may be globular, orbicular, ovoid, polyhedral, radiating, feathery. It consists of loose cellular tissue, and at the proper time secretes a viscid matter to detain the pollen.

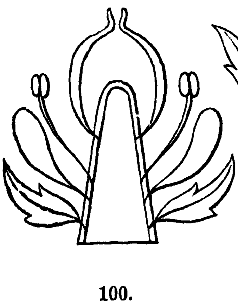
61. A pistil may consist of one single *carpel*, but it is usually formed by more than one; in the former case it is *simple*, in the latter, *compound*. The carpels in the compound pistil are either separate and distinct, in which case the term *apocarpous* is applied to the pistil, or they are united, in which case the term *syncarpous* is applied to it. The union of the carpels in the syncarpous pistil may be complete, or incomplete; in the former case, the number of carpels is indicated by the external venation, the grooves on the surface, and the internal divisions of the ovary; in the latter, by the number of styles and stigmata. The manner in which the carpels are united presents several modifications which exert some influence on the form of the fruit, and to which we shall have occasion to refer in the paragraph on the latter.

The pistil also affords some of the most important characters for the classification and description of plants. We must, however, remark here, that in many plants, *e.g.*, in firs and pines, the pistil is altogether absent, the ovules being naked, on which account these orders of plants are called *gymnospermæ* (see § 74).

Position, Adhesion or Union, of the Several Parts of the Flower, Suppression of Certain Parts.

62. In the preceding paragraphs we have examined the distinguishing characteristics of the several parts of the flower; we have now still to consider here certain points bearing on the arrangement and mutual relation of these several parts, and which are of some importance in the description and classification of plants. The first of these points relates to the position of the several verticils.

The regularly-formed *floral axis* presents a somewhat conical shape (fig.



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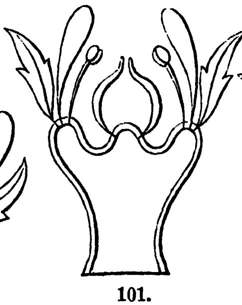

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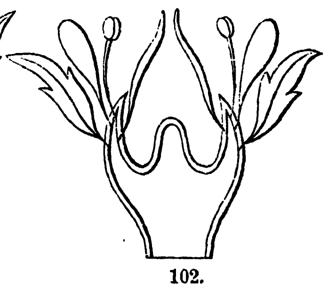

102.

100); if the four verticils occupy their proper normal position, each outer

whorl is placed *below* its inner whorl; in other words, the calyx is placed below the corolla, the latter below the stamens, and the stamens finally below the pistil. A flower in which the whorls occupy this normal position is called *hypogynous*. It frequently happens, however, that the lower part of the floral axis is raised, and forms around the apex a sort of *ring* (fig. 101), in which the outer whorls surround the pistils at a pretty equal height; in this case the flower is called *perigynous*. If the ring rises *above* the apex of the axis (fig. 102), the whorls are called *epigynous*, in relation to the pistils.

63. The different verticils of the flower are frequently adherent. Adhesions are observed more particularly between the calyx, corolla, and stamens, as is seen, for instance, in the rose, in the flower of the apple-tree, &c. In many plants the stamens and pistil are united, as in the orchidaceæ.

Flowers in which both stamens and pistil are present, are called *hermaphrodite;* those bearing stamens only are called *male flowers;* those having the pistil only, *female flowers*. When both these organs are absent the flowers are said to be *neutral*.

Plants bearing both male and female flowers on the same stem are called *monœcious*, as in the hazel and the oak. To those bearing the stamens and pistil on separate plants the term *diœcious* is applied; to this class belong mercurialis, hemp, the willow, hop, &c.

Accidental Parts of the Flower.

64. We designate by this term certain non-essential formations which are found only in some flowers; as, for example, the *crown*, an intermediate form between the petals and the stamens, which is seen very distinctly as a red ring, in Narcissus poetica. Analogous to this are the scales or scaly processes attached to the stamens in the boraginaceæ, for instance, in Myosotis palustris (Forget-me-not). Both these formations may perhaps be looked upon as bracts of the petals (§ 35).

Honey-cups or nectaries are pits or depressions on the petals filled with a saccharine juice; nectaried petals present sometimes a very peculiar form, resembling that of a horn or a spur.

Inflorescence or Anthotaxis.

65. Having thus examined, in the preceding paragraphs, the several parts of the flower, there remains now still for us to consider the arrangement of the flower on the axis; this arrangement is termed *inflorescence* or *anthotaxis*.

That part of a primary or secondary axis on which the floral verticils arise is called the *peduncle* or stalk. If this part happens to be very short, the flower is said to be *sessile*. A flower terminating a primary axis is called a *terminal* flower; all other flowers are said to be *lateral*. The term *axillary* is applied to the flowers produced in the axil of leaves.

A simple or branchless peduncle bears only one solitary terminal flower, as in the tulip; a branched peduncle bears several flowers.

The flowers are said to be *scattered* or *dispersed*, when they appear singly in different parts of the plants, and without any apparent arrangement.

Plants bearing flowers in clusters form several distinct groups, to which appropriate terms are applied indicative of their respective form of floral arrangement.

66. In the examination of this kind of inflorescence (*indefinite* or *axillary inflorescence*) the first object of remark is the general or primary peduncle, termed *rachis*, and which bears numerous leaflets called *bracteoles* or *bractlets*, from whose axils arise the *pedicellate*, or *sessile* flowers. The lower bracts often produce no flower-buds in their axils, and form instead a whorl surrounding the heads of flowers on the primary axis, and which is called *involucre* (as in the sun-flower, for instance).

67. The different varieties of axillary inflorescence are determined principally by the elongation or depression of the axis, the presence or absence of stalks to the flowers, and the form and nature of the bracts. We distinguish—

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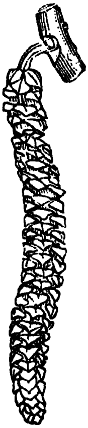

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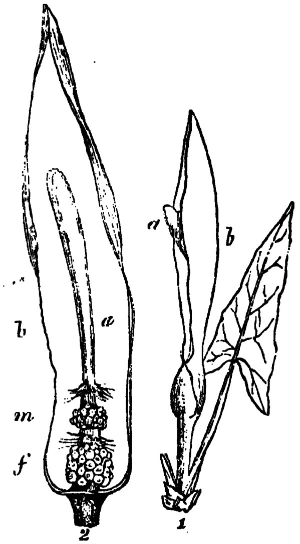

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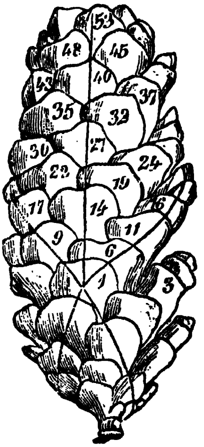


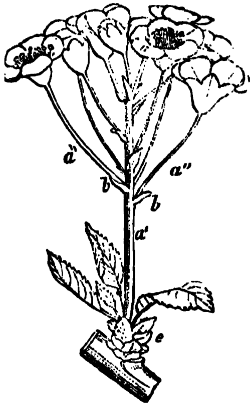
106.

1st. The *spike* (fig. 103). In this form of inflorescence, sessile or short-stalked flowers are arranged along the rachis in the axils of the bracts; the spike is said to be *compound* when small spikes or *spikelets* arise again from the bracts of the secondary axis. 2d. The *catkin* or *amentum* (fig. 104); a spike, usually pendulous, which falls off, rachis and all, by an articulation, as in the willow or hazel. 3d. The *spadix*, a thick fleshy spike (fig. 105); *examp.*, *arum* and *calamus.* 4th. The *cone*, a fruit-bearing spike covered with scales (fig. 106); *ex.*, the *coniferæ.* 5th. The *raceme* or *cluster*, a spike with the flowers on longer pedicels (fig. 107); *ex.*, the currant. 6th. The *panicle*, a branching raceme (fig. 108, *Yucca gloriosa*). 7th. The *thyrsus*, a dense panicle, with longer peduncles in the middle than at the extremities; *ex.*, *lilac.* 8th. The

corymb, a raceme, in which the lower flower stalks are elongated and raised

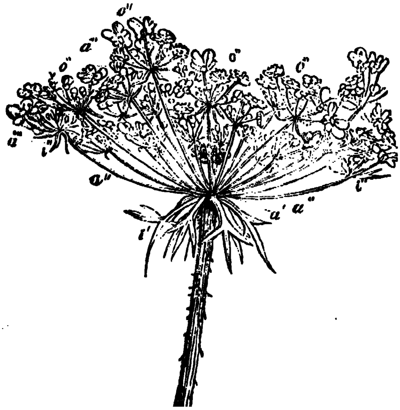
107.

108.



109.

to nearly a level with the upper (fig. 109—*ex.*, *cerasus mahaleb*). 9th. The *compound* or *branching corymb*, a corymb in which the secondary axis again subdivides; *ex.*, *Pyrus terminalis.* 10th. The *umbel:* in this form the primary axis is greatly depressed, and the peduncles arise from a common point, and spread out like radii of nearly equal length, a whorl of bracts (*involucre*) surround-



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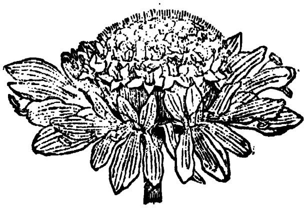


111.

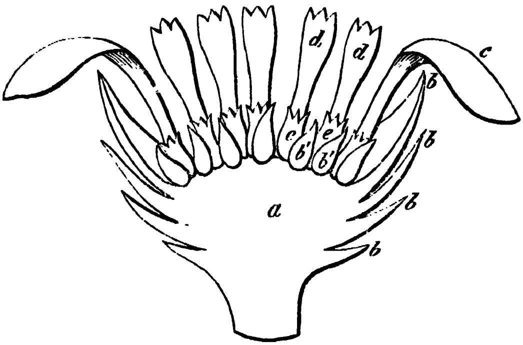
ing the common base. In the *compound umbel* (fig. 110—*Daucus carota*), the

secondary axes end again in small umbels (*umbellules*), surrounded equally by a whorl of bracts, which is termed an *involucel.*

This most remarkable mode of inflorescence characterises the great family of the *Umbelliferous* plants, to which belong, among others, hemlock, carrot, caraway, parsley, &c.

11th. Sometimes the floral axis or peduncle is considerably shortened and depressed, and bears numerous small flowers or florets either sessile or with very short pedicels, and arranged in a thick cluster, forming what is termed a *capitulum* or head, or a *glomerulus* or ball (fig. 111, head of flowers or glomerulus of *Scabiosa atro-purpurea*). The depressed axis is in these cases called a *receptacle* (or *phoranthium*, flower-bearer, or *clinanthium*, flower-bed). Sometimes the receptacle is considerably enlarged and expanded in form of a disk. This constitutes a very peculiar kind of inflorescence, which characterises the great family of the *compositæ*, and is illustrated by fig. 112.

We see here the enlarged floral axis or receptacle, *a*, surrounded by several whorls or bracts, *b b*, which constitute a general involucre; the membranous bracts (*paleæ*), *b′ b′*, seen in the receptacle, bear in their axils the sessile florets, *c* and *d*, which either have a calyx, *e e*, or not. The florets on the receptacle are either all of them *tubular* (*d*); or *ligulate* (tongue or strap-shaped); florets (*c*) are associated with the tubular ones. The receptacle is not always flat, but frequently presents a convex, globular, conical, concave, &c., shape.



112.

In the absence of *paleæ* the receptacle is said to be naked. The florets at the margin or circumference are termed *marginal flowers*, or *flowers of the ray;* the florets in the disk (*centre*), *central flowers*, or *flowers of the disk.*

The Fruit.

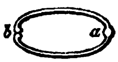
68. With the transmission of the pollen to the ovary of the pistil, the functions of the anther and stigma terminate; accordingly these parts of the flower rapidly wither and decay after fertilisation. The filaments, the style, and the petals speedily participate in the decay, but the sepals remain sometimes persistent in an altered form. The ovary and its contents alone proceed in their further development, and undergo material changes, in which, however, the bracts and the calyx often participate.

The fully developed and matured ovule, the *seed*, is, of course, regarded as the *essential* part of the fruit; the enlarged ovary forms the *pericarp*, enclosing the seed. The form of the pericarp determines the external appearance and the denomination of the fruit. As the structure of the fruit

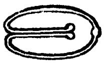
and the arrangement of its parts depends in a great measure upon the number and position of the carpellary leaves in the pistil, and the manner and extent of their union, and the extent to which their edges are folded inwards, we must here once more return to the consideration of that important organ.

69. The carpellary leaves occupy the summit of the floral axis. The axis terminates either in one single carpel, in which case the ovary is one-celled, or *unilocular;* or the axis is surrounded by several carpels, in which case the manner of their union determines the number of cells in the ovary.

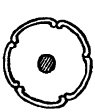
The accompanying figures represent horizontal sections of different ovaries, composed respectively of one carpellary leaf, or of several leaves in conjunction with the axis.



113.



114.



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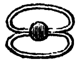

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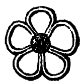
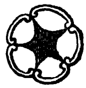


117.



118.

Fig. 113, shows the horizontal section of a one-celled or unilocular ovary formed by one single carpellary leaf; *a* marks the mid-rib of the leaf (the *outer* or *dorsal suture*), *b*, the margin of the folded leaf (the *inner* or *ventral suture*).

In fig. 114, the edges of the carpellary leaf are reflected inwards into the *loculament* or cell, which gives rise to the formation of an imperfectly *bilocular* ovary.

The *unilocular* ovary represented by fig. 115, is formed by the lateral union of five carpellary leaves standing round the axis. If the laterally united carpellary leaves are folded inwards, and unite with the axis, they form ovaries with two, three, five, or more cells, according to the number of carpellary leaves present (figs. 116 and 117). An outward expansion of the axis may also lead to the formation of an ovary with several cells (fig. 118).

Thus we see the form of the fruit foreshadowed in the ovary. The pericarp usually opens (in *dehiscent* fruit), when the seeds have arrived at maturity; and this dehiscence again takes place mostly at the suture formed by the union of the edges of the carpellary leaf.

Formation of the Fruit.

70. The carpels take the principal part in the formation of the fruit; they form the endocarp or core, and in many plants the whole of the pericarp. The floral envelopes and the bracts often contribute, however, to the formation of the epicarp and mesocarp. Upon the nature of these several parts of the flower, and upon the modifications which they undergo during the ripening of the seeds, depends therefore the nature of the fruit. We find that these parts sometimes remain foliaceous, or turn coriaceous, or

become hard, or fleshy, or pulpy, &c. The outer parts of a great number of fruits, consist of an accumulation of cellular tissue, containing starch, sugar, mucilage, oils, acids, &c., which are often of greater value for the use of man than the seeds themselves.

The more important forms of fruit are the following:—

a. Fruits which are the Produce of a Solitary Carpel.

71. (1.) The *gymnospermous* fruit, where the seed lies naked in the axils of the ligneous bracts, as in the cone of the fir and spruce tribe.

(2.) The *legume* or *pod*, which is formed of a solitary carpel bearing seeds on the ventral suture (fig. 113, *b*). It characterises the pea and bean tribe (*leguminosæ*).

(3.) The *follicle* is a mature carpel containing several seeds, and opening by the ventral suture. There are usually several follicles aggregated together; *ex.*, larkspur, monkshood, evergreen.

b. Fruits which are the Produce of Several Carpels United.

72. (4.) The *Capsule* consists of two or more carpels, either simply laterally united (one-celled or unilocular capsule, see fig. 115), or folded inwards towards the axis, but without reaching it (spuriously multilocular capsule), or uniting with the axis (bilocular, trilocular, multilocular capsule, see figs. 116 and 117). *Examples of capsular fruit*—mignonnette, balsam, violet, poppy, &c. (5.) The *Siliqua*, or long pod, is formed of two carpels, and longitudinally divided into two parts by a spurious dissepiment called the *replum*; *examples*—cabbages, stock, wallflower, &c. The *Silicula* is a broad and short pod; *examples*—Iberis, shepherd's-purse, &c. (6.) The *Cariopse* (*Caryopsis*, having the appearance of a nut), is a monospermous or one-seeded fruit, with an indehiscent membranous pericarp, closely investing the seed or incorporated with it; *examples*—rye, wheat, and other grains. (7.) The *Achænium* is a dry, monospermous, indehiscent fruit with one seed; *examples*—cashew, ranunculus, strawberry, &c. (8.) The *Nut* or *glans*, is a one-celled indehiscent fruit, with a hardened coriaceous or ligneous pericarp; *examples*—hazel-nut, acorn, &c. The *Nucula*, or *little nut*, is a cariopse, with a solid coriaceous pericarp; *examples*—buckwheat, hemp, &c. (9.) The *Berry* (*bacca*), is a pulpy succulent fruit, with soft rind; *examples*—the gooseberry and the currant. The *Pepo* or *peponida*. (pumpkin), illustrated by the fruit of the gourd and melon; and the *Hesperidium*, illustrated by the fruit of the orange and lemon, are modifications of the *berry*. (10.) The *Drupe* (*drupæ*, unripe olives); the mesocarp is generally pulpy and succulent, the endocarp hard; *examples*—the cherry, the peach, the plum, &c. (11.) The *Pome* (*pomum*, or apple); the outer parts of the pericarp form a thick cellular eatable mass; the endocarp (core) is scaly or horny, and encloses the seeds within separate cells; *examples*—the apple, pear, &c.

Fruits consisting of the floral envelopes and the ovaries of several flowers

united into one, are termed *multiple* or *anthocarpous;* the *Sorosis* (cluster-fruit: *example*—the pine-apple, the bread-fruit, the mulberry), the *Sycosis* (fig-fruit), and the *Strobilus* (fir-cone), form varieties of the *anthocarpous* or *multiple* fruit.

The Seed.

73. In the same way as buds spring from the stem in the axils of leaves, and produce branches, so there are formed in other parts of the more perfectly developed plant, buds of a somewhat different nature, which, when arrived at full maturity, form the seed, and are on that account sometimes called *seed-buds*, but more commonly, *ovules.*

The ovule is always found at the end of an axis, and with its maturation the growth of that part of the plant terminates.

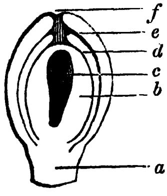
The seed-bud appears first as a small white cellular projection, which enlarges and assumes an ovoid form; a comparatively large cell in the interior forms a cavity called the *embryo-sac* (fig. 119 *c*).

The ovule is unable by itself to form the seed; its transformation into the latter can be effected only by the fecundating action of the pollen-grains upon it. Numbers of ovules perish undeveloped.

74. In many plants, as in the *Coniferæ*, for instance, the position of the ovule is very analogous to that of the common bud. It sits naked on the face of the scales of the cones arising from the axil of the membranous bracts. At a later period, we find the natural seeds naked at the base of the scales, as may be most distinctly seen in the large edible seeds of the *Pinus pinifera*, or Siberian stone-pine.

But in most plants, the ovule is produced in a certain foliaceous organ of peculiar structure, and which has been described already in § 60, under the name of *pistil.* This organ consists, as we have seen, essentially of two parts, viz., the *germen* or *ovary*, in the cavity of which one or several ovules are developed, and the *stigma*, which secretes a viscid fluid to detain the pollen. The pollen grains scattered over the stigma are conveyed to the ovules in the ovary either directly (in cases where the stigma is sessile), or through the conducting tissue of the *style*, an organ usually of cylindrical form, and which, as we have seen, is often interposed between the stigma and the ovary.

75. The *nucleus* of the ovule (fig. 119 *b*), remains naked in some plants;



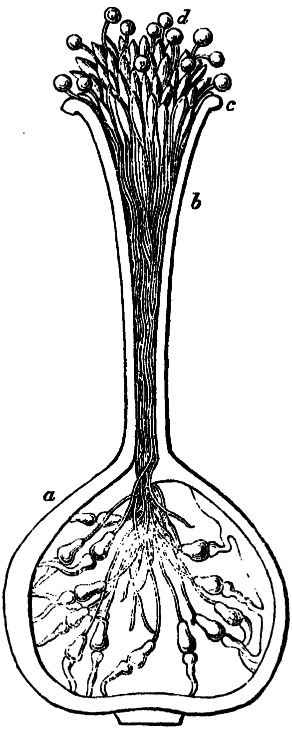
a Base of the ovule (Hilum).
b Nucleus of the ovule.
c Embryo-sac.
d The inner integument (secundine).
e The outer ditto (primine.)
f The foramen.

119.

but in most plants a covering or integument forms around it, enclosing every part, with the exception of the apex, where an opening is left, the

foramen (*f*). In many plants a second integument is subsequently formed; according to *Schleiden*, the *inner*, according to *Mirbel*, the *outer* integument is the first formed. The term *primine* is applied to the *outer* (*e*); *secundine*, to the *inner* integument (*d*), altogether irrespective of their order of development.

Fig. 119, represents a vertical section of a straight or erect (orthotropal) ovule properly magnified. In this ovule, the foramen at the apex is exactly opposite the hilum or base. Curvatures of the ovule in the course of its growth give rise to the so-called inverted or *anatropal*, half inverted or semi-*anatropal*, and curved or *campylotropal* (*camptotropal*) ovules. Some botanists ascribe the inversion of the anatropal and semi-anatropal ovule, to an elongated funiculus, folded along the side of the ovule, and completely or partially adhering to it. In the curved ovule, the foramen approaches the hilum, and ultimately is placed close to it; in the anatropal ovule, the foramen is placed in close opposition to the hilum.



120.

76. After a pollen-grain has lain for some time on the stigma, it is observed to swell and to project from the lower end a tubular prolongation called a *pollen-tube*. This tube proceeds through the stigma, and, where a style is present, also through the latter, down to the ovary, and passing through the foramen, enters the embryo-sac of an ovule. With this the impregnation is achieved, and there commences immediately at the part where the pollen-tube has entered, the formation of the embryo in the shape of a cellular body, or germinal vesicle, in the interior of which other cells are subsequently formed in a definite order of succession; this cellular mass shows after a time a separation of parts, so that the *ascending* and *descending* axis (the *gemmule* and *radicle* or *rootlet*), and the *cotyledons* or rudimentary leaflets, of the young plant can be distinctly seen.

Fig. 120 shows a vertical section of a pistil highly magnified; the grains of pollen, *d*, attached to the surface of the stigma, *c*, are seen to project in the form of tubes, through the style, *b*, down into the cavity of the ovary, *a*, and to penetrate the numerous ovules there.

77. With the development of the embryo, the cells surrounding it become filled with a deposit of solid matter, called *albumen*, and which encloses the embryo in some plants completely, in others only partially. The albumen cells contain usually albumen, starch, or oil, sugar, and other matters, which, irrespective of the various uses which we make of them, supply nutriment

to the young plant. However, there are also many plants in which the seeds have no such covering of albumen, but consist of the embryo and integuments alone, for which reason the term *exalbuminous* is generally applied to them. The integuments of the ovule may be traced again, though in a vastly altered form, in the ripe seed. The several parts of the embryo may be easily traced in the bean, for instance: we see there the placental attachment of the original ovule; and a transverse section shows the embryo or germ, surrounded by the albumen, and provided with its *radicle* or rootlet, and its *gemmule* or *plumule*, and *cotyledons* or rudimentary leaflets.

The embryo differs from the ordinary bud principally in this—that it constitutes a perfectly independent, though very minute, axis, provided with a root, and accordingly with the means of drawing its nutriment directly from the soil when put into the ground; whereas, the nutriment of the leaf-bud is always supplied by the intervention of other parts of the plant, until it has acquired sufficient vigor to send forth roots of its own when severed from the parent stem, and implanted into the soil.

The germination and further development and growth of the embryo, leads to the production of a new plant every way similar to the parent from which it has sprung; and thus the plant, though individually a perishable thing, still bears in itself the conditions of eternal existence.

II. VEGETABLE PHYSIOLOGY.

(GENERAL OBSERVATIONS ON VEGETABLE AND ANIMAL LIFE, AND ON THE VITAL PROCESSES, FUNCTIONS, AND PHENOMENA IN PLANTS AND ANIMALS).

78. By the term *vegetable* or *animal life*, we comprehend and designate the sum total of the action of all the organs of the animal or plant, and the processes and phenomena resulting therefrom.

The ultimate cause of this action, and of these processes and phenomena, is referred to a certain hypothetical force, which is designated as the *vital power*. But whether this *assumed* force *actually* exists, or is to be looked upon simply as the resultant of all the *known* forces of nature, acting under peculiar circumstances, and limiting and modifying each other, remains as yet a mystery.

There can be no doubt but that the physical and chemical forces, such as attraction, and more especially chemical affinity, play a most important part in the phenomena of life. The elucidation of the phenomena has been most materially advanced hitherto, by endeavouring to explain them as far as possible by the operation of the known forces and agencies of nature, attributing as little as can be to the intervention of an assumed vital power. In fact, it is by this means alone that we may hope ultimately to ascertain whether an independent force of this kind exists in reality, and, if so, to investigate and determine its laws. The term *vital power* should therefore be understood here simply as implying an *assumed* cause of certain processes and phenomena which, in the present state of our knowledge, are not referrible to the ordinary physical and chemical laws.

79. To this vital power must be referred more particularly the *organogenetic* and *organoplastic* faculty inherent in plants and animals. We may, indeed, combine all the constituent chemical elements of organic structures in due proportions of weight and measure, but, with all our knowledge and skill, and even though we should bring to bear upon the task all the known applications of all the known forces, we cannot even produce that simplest of organic structures, the *cell.*

80. The first and simplest manifestation of the vital power is the formation of the vegetable and animal cell, which constitutes the groundwork of all vegetable and animal tissues; and its expansion or growth in all directions, by the absorption and assimilation of certain new elements derived from without, and to which the name *nutritive matters* or *food* is given.

However, the growth of the organs produced by the vital power is limited both in space and time; regulated and restricted by laws and necessities concealed from human ken, the vital power produces indeed an infinite variety of individuals, but all of them are limited in form and extent.

When an individual (plant or animal), has once reached the full measure of growth assigned to it by nature, there is no further development possible for it, even under the most favorable circumstances. The action of the vital power may be considered to proceed with progressively increasing vigor up to a certain point of culmination; that point once reached, the energy of its manifestations decreases progressively in a similar ratio, until it drops to zero. The point at which the manifestations of the vital power cease, we designate as the *death* of the plant or animal.

From the moment of its death, the once living form becomes subject to the general laws of nature, and more especially to the force of chemical affinity, which destroys the organic structure, and decomposes it into a number of chemical compounds (Chemistry, § 158).

81. The vital power is limited also in the *variety* of its productions on earth. As far as our experience goes, it produces always the same forms over again, out of the same materials, after the same laws.

The *number* of individuals also, though truly enormous, is limited, being necessarily dependent upon the supply of food.

The individual bulk of any of the productions of the vital power is immeasurably small compared to the mass of the earth; yet the total aggregate of them covers the far greater portion of the earth's surface.

The duration of life in plants and animals presents infinite gradations. In some it lasts only a brief period of a few hours, or even less; others live the space of a few days, weeks, or months; in others, the term of life is lengthened to years; in some to centuries; and a few live to an age of several thousand years.

82. The vital power possesses simply the *formative*, *not* the *creative* faculty; in other terms, it cannot *create* even the minutest particle of the simplest organic structure, but must draw from without all the chemical elements out of which it forms the vegetable or animal organism.

83. In its faculty of appropriating new elements from without to the growth and development of its structures, the vital power resembles the force of chemical affinity, as exhibited in the formation of crystals (Physics, § 19; Chemistry, § 29.)

The laws governing the growth of organic beings are, however, essentially different from those which regulate the increase of inorganic bodies. Thus, as we have seen in Mineralogy, § 5, crystals present forms bounded by planes, rectilinear edges, and angles, whereas the spherical is the ground-form in plants and animals. We have to observe here that the angular or polyhedral forms of the vegetable cell arise simply from pressure suffered during the process of development (§ 9).

Moreover, crystals increase by the accumulation of fresh particles on the outside, which particles remain altogether unaltered in other respects; whereas, the plant and the animal elaborate in the interior of their organs the food drawn from without, and alter that food both in form and in chemical composition. In terms more briefly expressed, minerals are said to *increase from without*, plants and animals to *grow from within.*

The crystal is only limited in *form*, not in *extent;* and it might increase *ad infinitum*, if the requisite materials and conditions were given.

The living body is exposed to the operation of an infinite variety of external influences, which may more or less seriously alter or disturb the normal functions of the organs. These perturbations are marked by changes in the ordinary phenomena of life. The abnormal condition indicated by such changes is called *disease.* If the perturbations of the organic functions are of considerable extent or intensity, or of long duration, *death* is the general result.

The Vital Functions, &c. of Plants.

84. We have in the preceding observations, briefly touched upon the most general and prominent laws and principles concerning the life of the animal and the plant; and in reference to the life and functions of the latter, we have already, in the sections devoted to the Organographic part, incidentally given such information as may be deemed sufficient for the scope of an elementary work like the present.

There are, however, a few points which demand more ample consideration; and among these, the *nutrition* of plants occupies the principal place, on account of its great importance in the cultivation of plants, and more especially of the grasses and cereals.

Nutrition of Plants.

85. To arrive at correct notions on this subject, we have to examine and study on the one hand, the organs of the plant and their functions, and on the other, the food which they derive from without, and the changes which this food undergoes in the vegetable organism.

The first inquiry which suggests itself here, is, what is the nutriment of plants?

To answer this inquiry, we must ascertain what are the chemical elements that constitute the body of the plant. For, since, as we have seen in § 82, the plant cannot *create* even the minutest particle of its own substance, it is obvious that its constituent particles must all be derived from without.

Now, we have seen in § 7 that the great bulk of the plant is composed of cellular tissue and vascular tissue, or so-called woody fibre; and that the cells contain partly solid matter, such as starch, chlorophylle, resins, salts,

and partly a watery juice or sap, which holds in solution sugar, gum, mucilage, acids combined with metallic oxides, albumin, &c.; to which are to be added, in many plants, volatile and fixed oils.

Daily experience teaches us also that the great bulk of the plant is, upon combustion, converted into gaseous compounds, which pass into the air, leaving behind only a most inconsiderable residue, which contains the non-volatile metallic oxides and salts, and which is called the *ash* of the plant.

Now, are we to infer from this that starch, woody fibre, oil, albumin, &c., constitute the nutriment of plants?

Were this the case, the soil, the water, and the atmosphere, in which the plant has its existence, must contain these substances, so that the plant need merely assimilate them, and convey them to the part where they are required.

But such is not the case. We nowhere meet with starch, woody fibre, sugar, albumin, &c., except in the plant itself; which clearly proves that the plant must possess the faculty of forming these substances out of the chemical elements.

Hence it follows, *that the chemical elements which we find combined in the organic structures that compose the vegetable body, constitute the nutriment of the plant.*

86. In the chemical part (§ 116), we have seen that the chemical elements which combine to form organic compounds are, *Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur,* and *Phosphorus.* Some of the organic compounds contain two of these elements; others three, others four, and a few five, or even the whole six of them. Thus,—

The volatile oils are formed of	*Carbon* and *Hydrogen.*
The vegetable acids, woody fibre, starch, gum, mucilage, sugar, fats, resins, coloring matter, ...	*Carbon, Hydrogen,* and *Oxygen.*
The organic bases, ...	*Carbon, Hydrogen, Oxygen,* and *Nitrogen.*
Caseine, ...	*Carbon, Hydrogen, Oxygen, Nitrogen,* and *Sulphur.*
Albumin and fibrine, ...	*Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur,* and *Phosphorus.*

All these organic substances are completely consumed by the action of fire, on which account they are termed also the *combustible* constituents of plants, in contradistinction to the incombustible parts which remain as ashes upon the combustion of the plants.

The examination of the ashes of plants reveals the presence in them of the following substances:—

ACIDS.	METALLIC OXIDES.
Carbonic acid.	*Potassa.*
Silicic acid (Silica).	*Soda.*
Phosphoric acid.	*Lime.*
Sulphuric acid	*Magnesia.*
Nitric acid.	Alumina.
	Sesquioxide of iron.
	Sesquioxide of manganese.

To which are to be added *Chloride of Sodium,* Chloride of Potassium, and in marine plants, Iodide of Sodium (an *invariable* constituent of marine plants), and Iodide of Magnesium.

The acids and metallic oxides in *italics* are found in every vegetable ash, and are therefore to be regarded as essential constituents of plants; whilst those in common type are found only in certain species, or are present in such minute quantities only that they cannot be looked upon as indispensable to the existence of the plant.

The mineral constituents do not form any distinct organic tissue or structure in the plant, but are either held in solution by the sap, or are lodged in a solid form (as crystals) within the cells (§ 10). Thus, for example, the cells on the margin of the leaves of many grasses contain so great a number of minute hard silica crystals, that the edges of the leaves cut like a knife.

The *Equiseta*, or shave-grass plants, contain large quantities of this earth, which has led to their use for polishing wood.

Carbonates of metallic oxides are not found in the living plant; but carbonic acid is a product of the decomposition of the organic acids (oxalic acid, tartaric acid, &c.), ensuing upon the combustion of the plant. The same applies also to a portion of the sulphuric acid and phosphoric acid.

87. Each individual plant represents accordingly a kind of magazine or store, containing a variety of elementary matter in unequal relative proportions. We have seen that not one of these elementary matters can be created by the plant, and that they consequently must all of them be derived from without. Therefore, if a plant does not find within its reach the requisite materials for the formation of its component parts, it perishes, or at all events, its development is checked to a greater or less extent.

Plants do not all contain the same constituents, in the same relative proportions; however, all plants belonging to one and the same genus or species, require the presence of the same constituents in certain proportions.

Nature provides everywhere the means requisite for the growth and development of plants, but in very different quantities. The steep rock, the morass, the shifting sand, the deep sea, the ploughed field, the rubbish heap, and the trim garden—they all feed plants, and are covered with them; but the plants are not the same in their several parts—they differ as greatly as the different places whereon they respectively grow.

Now, the object of agriculture is, to provide those external conditions requisite to enable a certain class of plants, which are of especial use to mankind, to derive from the soil in which they grow a sufficient quantity of the elements necessary for their growth and development.

It is impossible to arrive at a clear notion respecting these external conditions of vegetable life, if we do not most accurately know the constituent elements of the plant, and the ways and channels through which these constituent elements are admitted into the vegetable organism.

We shall, therefore, in the following paragraphs, treat, first of the absorption (assimilation) of the combustible constituents, and afterwards of that of the mineral constituents of plants.

Absorption of the Combustible Constituents of Plants.

88. We shall confine ourselves here to the following five elements, leaving the sixth, phosphorus, out of consideration:—

1. Carbon. 2. Hydrogen. 3. Oxygen. 4. Nitrogen. 5. Sulphur.

1. Absorption of the Carbon.

We have seen in § 11, that the cell can only absorb matter in a state of solution. Accordingly, carbon, being in its elementary form totally insoluble in water, cannot be absorbed in that form. The whole of the carbon found in a plant has entered the vegetable organism in the form of a compound soluble in water, viz., *carbonic acid*, which, as we have seen in the chemical part (§ 53), is composed of carbon and oxygen.

Carbonic acid plays a most important part in the nutrition of plants.

Now, here arise the following questions:—Whence do plants derive their carbonic acid? how do they absorb it? and in what manner is the carbonic acid made use of in the plant?

The answer to the first question would seem easy enough. We have seen in the chemical part (§ 165), that the soil contains a quantity of vegetable and animal matters in a state of decomposition, and which are designated as *humus*. The principal product of the decomposition of this humus is carbonic acid, a substance highly soluble in water, and which may, therefore, be readily taken up along with the water absorbed by the roots. This explanation would appear the more probable, as we usually observe in parts blessed with a luxuriant vegetation, that the soil is covered with a thick layer of humus, or looks quite black from the presence of that material. It is upon these grounds that humus has been looked upon as the principal source from which plants derive their nutriment.

However, upon a closer inspection and consideration of the matter, we find that this view is erroneous, and that the humus is not the *source*, but the *product* of the vegetation.

The history of the earth's formation (see Mineralogy, § 115), teaches us that the whole mass of our globe was originally in a state of igneous fusion, and that the earth's crust has been consolidated by cooling. Now it is self-evident that this consolidated crust could not possibly contain a layer of humus. Whence, then, did the first vegetation derive its nutriment? Nay, even to the present day we see that a bare rock raised up from the sea by volcanic action, gets speedily covered with vegetation; that a luxuriant crop of plants springs on disintegrated lava; that on a sandy soil, containing a most minute quantity of organic matters, woods and meadows may be planted with the best results—finally, that cactus and house-leek will grow on the bare rock, or on walls and roofs, where there is not a particle of humus to be found; and that we may grow forget-me-not, cresses, and hyacinths, in pure water.

The following facts are still more striking:—We see that plantations of every kind, cultivated on a soil deficient in humus, continually increase the quantity of the latter, instead of diminishing it. From the sugar and coffee plantations, and from the banana fields, there are many millions of pounds of carbon carried off annually in the products of the harvest, and no attempt is ever made to replace this carbon (by manure, for instance); and yet the quantity of humus in the soil increases, instead of diminishing. In the hay yielded by an acre of fertile meadow, 2,000 pounds of carbon are carried off; and yet, though the same amount of carbon is abstracted year after year, the necessity does not make itself felt to replace this carbon by artificial supplies.

These facts clearly show that the humus cannot possibly be the source of the carbonic acid, which serves to feed the plants. It is the *atmosphere* that we have to look upon as the great store from which plants derive this, their principal nutriment. True, the atmosphere contains in 5,000 volumes only two volumes of carbonic acid; but, notwithstanding this small relative proportion, the prodigious extent of the atmosphere makes the average total amount of the carbonic acid in it, as much as 8,440 billions of pounds—a store more than amply sufficient to maintain a vegetation covering the whole surface of the earth.

The carbonic acid may be absorbed directly from the air through the stomata of the leaves. That this is actually done, has been clearly established by experiments. Air containing carbonic acid was transmitted through a balloon in which green leaves or branches were placed; the result proved a total withdrawal of the carbonic acid. Still the chief bulk of the carbonic acid required by the plant, is taken up in combination with water, by the roots.

The constant and continued drain upon the carbonic acid of the atmosphere must, of course, tend to reduce the relative amount of that gas present in the air. But if we consider, that, by the respiration of animals, by the processes of combustion and putrefaction, and finally by volcanic eruptions, large quantities of carbonic acid are continually restored to the atmosphere, we can readily understand that the amount of that gas present in it should remain quite stationary, at least as far as we can judge of the fact.

89. Regarding the manner in which the carbonic acid is made use of in the plant, the general opinion is, that the acid undergoes decomposition, the carbon being appropriated by the plant, whilst the oxygen is eliminated through the leaves.

There can be no doubt but that the leaves and the other green parts of the plant provided with stomata, do exhale oxygen as long as they are exposed to the influence of the solar rays. Still it is not impossible that the carbonic acid may be appropriated unaltered. In that case, the oxygen given off by the leaves would have to be regarded as proceeding from the decomposition of a portion of the water absorbed by the plant—the hydrogen being assimilated, the oxygen eliminated.

90. Though, as has been demonstrated above, the humus of the soil is the *product*, and not the *source* of vegetation, still, on the other hand, there can be no doubt but that the presence of humus in a soil exercises a most favorable influence upon the vegetation growing on that soil. It is this undoubted fact that led to the notion so long entertained, and so pertinaciously defended, viz., that the humus is the principal source of vegetable nutrition. However, as has already been intimated, this notion is sufficiently refuted now, by the equally well-established fact, that splendid harvests are occasionally reaped in soils very poor indeed in humus, whilst, on the other hand, we find that fens and bogs, which consist almost entirely of humus, yield a very poor vegetation.

Humus is just as insoluble in water as carbon is; to understand its favorable influence upon the growth of plants, we must, therefore, bear in mind that it consists of organic remains in a state of decomposition, and that among the products of that decomposition there are some which are soluble in water,

either alone, or in combination with ammonia (humic acid, ulmic acid); and, moreover, that the ultimate product of the decomposition of all organic substances, and accordingly also of humus, is carbonic acid. A soil abounding in humus, will, therefore, always contain a large amount of carbonic acid; and the water penetrating the soil will thus become saturated with that acid, and convey it subsequently to the plants.

But humus, has, besides, some other properties which greatly increase its fertilising power. It possesses in a higher degree than any of the other usual constituents of the soil, with the exception of clay alone, the property of attracting and absorbing water from the atmosphere. The black color which it gives to the soil, lays the latter much more open to the influence of the caloric rays of the sun, than is the case with the lighter-colored soils (see Physics, § 145).

It imparts also the proper degree of looseness to the soil, to make it accessible to the contact and influence of the atmospheric oxygen. Besides, the decomposition everywhere in progress in soil abounding in humus is attended with a disengagement of heat, highly favorable to the growth of plants, as we see so clearly evidenced in hotbeds.

The relative amount of humus present in a soil may, to a certain extent, be guessed from the black color of the latter; however, a more accurate result is arrived at by igniting a portion of the soil, dried previously at 212°; by this means, the combustible humus is destroyed, the products of its combustion being dissipated in the air, and the mineral constituents of the soil are left behind.

91. During the night, and in darkness (in cellars, for instance), there is no absorption and no elimination of oxygen through the leaves. The exclusion of light exercises a modifying action upon the whole of the vital functions and processes of the plant. The plant may indeed form new parts in the dark, but the requisite materials are, in that case, taken out of its own substance, and are not derived from without, as may be clearly shown in the potatoes which put forth shoots in the dark. Many of the secretions of plants, as chlorophylle, the bitter milky juice of the *Cichoraceæ*, the acrid oil of the *Cruciferæ*, are formed only under the influence of light. Plants growing in the dark are colorless; the inner leaves of the lettuce, the endive, the white cabbage, are white, and in the two former, they have no bitter, in the latter no pungent taste. On the other hand, some other matters are formed in certain plants, or in certain parts of plants, removed from the influence of light; *e.g.*, sugar in the white cabbage, solanine in the germ of the potato.

If we put a plant under a glass bell during night time, the air in the bell is found to contain in the morning an increased amount of carbonic acid. This is most probably occasioned by the oxidising action which the oxygen of the air surrounding the plant exercises upon the surface of the latter, giving thus rise to the formation of a certain amount of carbonic acid, greatly differing in different plants, but most considerable in such as contain readily oxidisable volatile oil in their glands.

2. Absorption of the Hydrogen and Oxygen.

92. In most parts of the plant which contain hydrogen and oxygen, we find the relative proportions of these two bodies to stand as one to eight,

which is the same proportion in which we find them combined in water. (Chem. § 28).

We take it therefore for granted that these two elements are taken up in the form of water, the absorption being effected almost exclusively through the roots: however, many vegetable substances, and more particularly the volatile oils and the resins, contain no oxygen by the side of the hydrogen, or contain the former element in a less proportion than it is present in in water; which fact evidently shows that the plant must possess the property of decomposing also a portion of the water absorbed by it, assimilating the hydrogen, and eliminating the oxygen.

The presence of water is accordingly absolutely indispensable for the development of the plant. However, the latter absorbs a much larger quantity of that substance than is required for its nutrition and development. The excess of water absorbed is thrown off again by evaporation through the leaves.

The leaves possess also the property of absorbing aqueous vapor; were this not the case, the dew could not have the beneficial influence on vegetation which it certainly exercises.

We shall have occasion to recur to this part of the subject, in the chapter on the absorption of the mineral constituents of the plant.

3. Absorption of the Nitrogen.

93. The quantity of the nitrogen contained in plants is small compared to that of the other constituents. The nitrogen is found principally in the sap of the cells, more particularly of the youngest parts and shoots, and in the seeds. In 2,500 pounds of hay are contained 984 pounds of carbon, to only 32 pounds of nitrogen.

Though the leaves of the plant are constantly surrounded by the nitrogen, which constitutes four-fifths of the atmosphere, yet they do not absorb a particle of it.

All the nitrogen which a plant contains has been absorbed by it in the form of *ammonia*, a chemical compound consisting of nitrogen and hydrogen (Chemistry, § 78). This substance, which is characterised by its penetrating odor, is highly soluble in water, and is accordingly taken up by the water along with the latter body.

The atmosphere which, as we have seen, is the source of the carbon, is also that of the nitrogen contained in the vegetable and animal body. In a purely mineral soil, nitrogenous minerals are a rarity, to be met with only in certain localities, as in the nitrate of soda, for instance, found in Chili.

The atmosphere, on the contrary, contains everywhere a certain amount of ammonia, which, though inappreciable in weight, and so small indeed that it cannot be detected in the air by the smell, is still clearly traceable in rain water, and in the water of brooks. The arable soil, more particularly if abounding in clay and in humus, eagerly absorbs the ammoniacal gas; and thus this nitrogenous body is diffused everywhere, and conveyed within reach of the roots of the plants.

An extensive and luxuriant vegetation, and the animal kingdom subsisting on it, would unquestionably in the course of time exhaust the ammonia of the atmosphere; but as the decay of organic substances serves to restore the

carbon to the atmosphere, in the form of carbonic acid, so ammonia is a constant product of the decay and decomposition, more particularly of animal substances (manure), for the simple reason that these substances contain a large proportion of nitrogen. An additional supply of ammonia is furnished to the atmosphere by the volcanos, which evolve that gas in considerable quantities.

Nitrogen being one of the essential constituents of the vegetable organism, we can readily understand the favourable action and influence exercised upon vegetation by matters which either contain ammonia ready formed, such as putrefying manures, ammoniacal salts, &c., or which, put into the soil, gradually suffer decomposition, attended with the generation of ammonia—as is the case, for instance, with animal offals of every kind, such as the raspings and cuttings of horn, ground bones, &c.

4. Absorption of the Sulphur.

94. The amount of the sulphur contained in plants is still less considerable than that of the nitrogen. It forms, however, an essential constituent of vegetable albumen, caseine, and fibrin, which bodies contain from ½ to 2 per cent of sulphur (see Chemistry § 150).

The whole of the sulphur met with in a plant has been taken up by the roots, in the form of *sulphuric acid*, which latter substance we have accordingly to regard as one of the elements of plants. Sulphuric acid is found in small quantities in almost every soil, chiefly in combination with lime, in the form of gypsum. This salt (gypsum) being slightly soluble in water, a portion of it is taken up by the roots along with that fluid. Besides, all manures contain *sulphate of ammonia*, a salt which, on account of the nitrogen and sulphur contained in it, is highly conducive to the proper growth and development of those parts of the plant that number these elements among their essential constituents.

Absorption of the Mineral Constituents of Plants.

95. The mineral constituents of plants are combinations of silicic acid, phosphoric acid, and sulphuric acid, with potassa, soda, lime, and magnesia; and, beside these, chloride of potassium and chloride of sodium. Alumina, sesquioxide of iron, sesquioxide of manganese, nitric acid, and iodine, are more rarely met with in plants.

The sum total of these incombustible matters constitutes but a very small proportion of the weight of the plant. 100 lbs. of the following vegetable substances are found to yield the annexed quantities of ash:—fir-wood, $\frac{8}{10}$ lb.; oakwood, 2½ lbs.; wheat-straw, 4½ lbs; limetree-wood, 5 lbs.; potato-haulm, 15 lbs.

The quantity of mineral matter varies in different species, and in different parts of the same plant. The leaves, the seeds, and the bark usually contain a far larger quantity of mineral constituents than the stem and roots. 100 lbs. of fir-leaves are found to give 8 lbs., and the same quantity of oak-bark and oak-leaves, from 8 to 9 lbs. of ash.

But it is not the *quantity* of the ash alone which varies in different species of plants, but also its composition, as the following table shows:—

There are contained in—

	Potassa- and Soda-Salts.	Lime and Magnesia-Salts.	Silicic Acid.
100 parts of ashes of:—			
1. Wheat { Straw, ...	22·00	7·00	61·00
2. Wheat { Grain, ...	47·00	44·50	0·5
3. Barley { Straw, ...	20·00	20·20	57·0
4. Barley { Grain, ...	29·00	32·5	35·5
5. Pea Straw, ...	27·82	63·74	7·81
6. Clover, ...	39·20	56·00	4·90
7. Potato { Haulm, ...	4·20	59·40	36·40
8. Potato { Tubers, ...	85·81	14·19	...
9. Beetroot, ...	88·00	12·00	...
10. Turnips, ...	81·60	18·40	...

The preceding table clearly shows that the composition of the ash varies in different species of plants, and even in different parts of the same plant; thus, whilst the ash of *pea-straw* is found to contain 63 per cent of lime salts, that of *wheat-straw* is seen to contain 7 per cent of them, and that of *wheat-grain*, again, 44 per cent.

These facts lead to the conclusion, that every plant requires for its growth and development certain mineral substances in certain proportions.

All these mineral substances are derived in a state of solution from the soil, and are accordingly taken up exclusively by the roots.

If the soil is without them, or contains them only in insufficient quantity, those parts of the plant which require their presence will not form, or will, at all events, be only imperfectly developed.

Careful experiments have fully confirmed this fact:—

In pure quartz sand the pea, for instance, will germinate and grow, but it will form no seeds; whereas, if we add to the quartz sand salts of lime and potassa, the pea planted in this mixed soil will produce a perfect plant, seeds and all.

96. Whilst carbonic acid, water, and ammonia, which supply the carbon, hydrogen, oxygen, and nitrogen of the plant, are found diffused everywhere in sufficient quantity, the inorganic constituents of plants are most unequally distributed.

We have seen in mineralogy that the inorganic part of the soil consists simply of disintegrated rock; upon the nature of the latter depends accordingly the kind of mineral constituents present in a soil. If, for instance, the soil is the product of the disintegration of pure limestone, it will only contain lime; if pure quartz, it will only contain silica. Neither of these will afford to vegetation the necessary alkalies. The mixed rocks, on the contrary, and more especially granite, basalt, porphyry, clay-slate, greywacke, lava, contain all the metallic oxides found in the ashes of plants, and furnish, accordingly, the most fertile soils. (Comp. Mineralogy, § 84–104.)

97. In the seeds or grains of the cereals, and in most other seeds, we find the lime and magnesia invariably combined with *phosphoric acid*. One hundred pounds of the ashes of wheat grain yield 45 pounds; 100 pounds of the ashes of the yellow boiling pea, 34 pounds of phosphoric acid. Native

phosphate of lime (*apatite*) is rather rare in the mineral kingdom (Mineralogy, § 36). The phosphate of lime found in the seeds has been taken up in solution by the roots in the same way as the other inorganic constituents of the plants. The seeds of the cereals and grasses supply man and the animals with the phosphate of lime required for the formation and nutrition of the osseous frame (Chemistry, § 51).

98. In many species of plants, one of the inorganic constituents is present in a much larger proportion than any of the other. Thus silicic acid predominates in wheat, lime in peas, potassa in edible roots and tubers (see § 95).

This has led to a division of plants into *silica plants*, *lime plants*, and *potassa plants*.

To the *potassa plants* belong wormwood, orach, beetroot, turnips, maize.

To the *lime plants*, lichens, cactus, clover, beans, pease, tobacco.

To the *silica plants*, wheat, barley, rye, oats, and the cereals and grasses in general; also heath, broom, buckwheat, acacia.

In most plants, the seeds or grains belong to one, the stem to another of these categories; such plants are generally adapted for a wide dissemination.

99. Now that we know the importance of the mineral constituents in the economy of plants, we can account also for the isolated or exclusive occurrence of certain plants in certain localities. Thus, for instance, we find the *wild* celery, and the so-called *halophytes*, or salt-plants, as *salsola*, *salicornia*, &c., only near the sea shore, or near saline springs, because these plants require a considerable quantity of soda, which they could not meet with in other localities. *Borage* and the *thorn-apple*, again, grow exclusively in the vicinity of inhabited places, as they require a certain supply of saltpetre, which is derivable only from the decomposition of animal substances (excrementitious matters, &c.) (see Chemistry, § 69).

So we observe, also, in many localities, a total absence of certain plants, which yet we find growing in profusion close by, but on a different soil.

In the argillaceous soils of the banks of the Wey and Thames, the purple heath and yellow broom are looked for in vain, while at the distance of a few miles, on St. George's Hill, Esher and Dartford Heaths, the ground is completely covered with these plants.

The presence or absence of such characteristic plants afford the surest indication of the nature of the soil, and often enables us to dispense with a chemical analysis of it.

100. The *water* in the soil serves not only to convey to the plant the carbonic acid and the ammonia, but also to dissolve the mineral constituents, and thus to fit them for absorption by the roots of the plants.

Without the water to dissolve these fertilising agents, and fit them for absorption, they would prove but a barren treasure.

The property of the soil to attract and absorb moisture, and to retain it for a time, depends upon the presence of *clay* in it (Mineralogy, § 49).

A superabundance of clay is as detrimental to the agrarial usefulness of a soil as a deficiency of that material is. Over-clayey soils are constantly wet, and too closely lumped together to be properly accessible to atmospheric influences; and when a long-continued drought has at last succeeded to dry them up, they constitute a hard mass which baffles all attempts of the roots to penetrate through it. Only rushes and reeds—hence also called *clay plants*—thrive on an over-clayey soil, and even these do only indifferently well there

MANURE.

101. It has been ascertained by actual experiment that a crop of wheat abstracts from a field of 10,000 □ metres * (about $2\frac{1}{2}$ acres English) in extent, 130 lbs. of potassa-salts, 67 lbs. of lime-salts, and 260 lbs. of silica, making a total of 457 lbs. of mineral matters. Of these, 112 lbs. are phosphates. Now supposing a similar crop to be taken from the same field, for several successive years, it is obvious that very considerable quantities of these mineral matters must be abstracted from that field, and that the surface of its soil must, therefore, necessarily grow poorer and poorer in them, until ultimately it can no longer afford the requisite supply of mineral constituents to the growing plants: the inevitable consequence of this will be a gradual falling off in the produce of the impoverished field, until at length the yield will no longer repay even the trouble and expense of sowing. If we wish to reap year after year from the same field, we must annually restore to the land the same amount of the essential mineral constituents as has been abstracted from it by the year's crop. This is effected by the process of *manuring*.

The dung of cattle, night soil, dried ox blood, and other animal matters of the kind, contain phosphates and sulphates. Put on a field, they restore it to a proper condition to afford to the crop growing on it the requisite supply of these inorganic constituents; they are useful, moreover, as a source of carbonic acid and ammonia. Besides the excrementitious matters, &c. of man and the animals, there are many other substances which may subserve the purpose of manuring.

Coprolites (ground and mixed with sulphuric acid), gypsum, bone-dust, wood-ashes, turf and coal ashes, soap-ashes, quicklime, the ammoniacal liquor of gas-works, and the ammoniacal refuse of some other works of the kind, afford most valuable manures.

The more accurately the chemical composition of a soil is known, the easier will be the choice of the proper manure for it. A few bushels of the substances demanded by the nature of the soil and of the intended crop will prove more fertilising than whole cart-loads of unsuitable manures.

There are more particularly two substances which have hitherto been found to exercise a most beneficial effect upon the fertility of a field, even though used only in comparatively small quantities. These two substances are, *gypsum* and *bone-dust*.

The fertilising properties of gypsum have been long known in Europe. *Benjamin Franklin*, struck with the richness of the crops which he saw gathered in our part of the globe, from fields and meadows manured with gypsum, endeavoured to introduce into his own country the use of that substance as a manure; but he found it difficult to persuade the American farmers to give it a trial, as no one of them would believe in the promised wonders. Therefore, to convince them of the truth of his allegations, he strewed gypsum on a sloping field, in a manner to form in enormous letters the words "*Effects of gypsum.*" The luxuriant growth of the plants sown on the part so prepared, and which made the words clearly legible to the passers-by, established the new manure at once firmly in popular favour.

Gypsum is a compound of sulphuric acid and lime (Chemistry, § 81); it contains accordingly two of the essential constituents of plants (sulphur and lime).

The fertilising action of gypsum is variously accounted for. Some would

* One metre = 39·37 inches English measure.

ascribe it to the sulphur which that salt contains; others, basing their opinion upon the favourable influence which it is found to have upon the yield of lime plants, and more particularly of clover, attribute it to the lime in it. No doubt both the sulphur and the lime have their share in the good effects produced by the gypsum; but this substance serves, moreover, to fix a portion of the ammonia in the soil which would otherwise escape into the air. This is effected by a double decomposition ensuing between the gypsum and the carbonate of ammonia in the soil, which results in the formation of carbonate of lime on the one side, and of sulphate of ammonia, a much less volatile compound than the carbonate, on the other. Carbonate of lime, again, is soluble in water containing carbonic acid; this menstruum it meets with in the soil, and thus the requisite condition is given for its conveyance into the body of the plant through the ordinary channel of the roots. The facility with which the fine gypsum powder is diffused over a field, and its comparatively ready solubility in water, contributes also to its usefulness as a manure.

Bone-dust exercises a most beneficial influence upon the soil, more particularly in the production of wheat crops. The fertilising action of this manure is attributable to the nitrogen in the gelatine of the bones, and to the presence of phosphoric acid and lime. The more finely ground the bones are, the more profitable they prove as a manure. Admixture of sulphuric acid heightens the fertilising effects of bone dust.

Oil cakes have been used of late as manure with great success.

FALLOW.

102. A field exhausted by successive crops may be restored again to productiveness, even without the application of manure, simply by leaving it uncultivated for one or several seasons. This is called *fallowing*, and is extensively resorted to in many thinly populated districts.

The restored productiveness of a field from being allowed to lie fallow for a time, is easily explained. The air and water incessantly exercising their disintegrating action upon the soil, a fresh amount of the soluble mineral constituents is continually being rendered accessible to the plants of a new crop. We can understand this the more readily if we bear in mind that most of the salts absorbed by plants are very difficultly soluble in water, and that it requires accordingly some time for the water penetrating into the soil to get saturated with them. A field lying fallow gets speedily covered with weeds, which serve to retain the moisture in the ground, and increase also the amount of humus.

Soils only of the most favourable chemical composition, such as disintegrated lava, for instance, will produce crops uninterruptedly without either fallow or manuring.

ROTATION.

103. We have seen in § 95 that the inorganic matters which enter into the composition of plants vary considerably in their nature and relative proportions in the different species. Whilst a field of about $2\frac{1}{2}$ acres loses 112 lbs. of phosphates by a crop of wheat, a crop of turnips takes only 38 lbs. from the same extent of land. It is obvious, therefore, that a field may produce three successive crops of turnips without being more exhausted by the three than by one crop of wheat.

This explains the reason why a soil that is exhausted with respect to one

species of plants, may still produce a crop of another species, and after this, another crop of a third species. Thus a crop of clover or of potatoes may be grown after a crop of wheat, without manuring the field, since these two plants require only a very trifling proportion of phosphates.

The proper succession to be followed in the rotation of crops, depends, of course, always upon the nature and chemical composition of the soil of the locality. With a judicious shifting of crops, one thorough manuring will suffice for from five to seven harvests; and with a proper selection of manure, the system of fallowing, which is almost impracticable in densely inhabited countries, may be dispensed with altogether.

AGRICULTURE.

104. A disquisition on this most important of all the industrial occupations of man, would exceed the limits of an elementary work like the present. What has been said in the preceding sections on the subject of the structure and functions of the organs of the plant, its constituent elements, and their absorption, will suffice, however, to point out to the farmer the advantages which he may derive from the study of the *science* of agriculture.

The prosperity of agriculture forms a safer foundation for the welfare of a people than the most flourishing state of any branch of manufacturing industry. The paramount importance of the tillage of the soil has been acknowledged in all ages. The ancients adored *Ceres*, their goddess of agriculture, also as the goddess of civilisation. The Emperor of China puts his hand once every year to the plough, to show his subjects the high estimation in which agriculture ought to be held.

We cannot abstain here from quoting the simple and pathetic appeal addressed by a chief of the red Indians to his tribe, to induce them to take to agricultural pursuits:—

"See ye not that the pale faces feed on grains, where we feed on flesh? That the flesh takes thirty months to grow up, and that it is often scarce? That every one of those wonderful grains which they strew into the earth, yields to them a thousandfold return? That the flesh on which we live, has four legs to flee from us, whilst we have only two to run after it? That the grains remain and grow up in the spot where the pale faces plant them? That winter, which is the season of our toilsome hunting, is to them a season of rest? No wonder, then, they have so many children, and live longer than we do. Therefore I say to every one of you who will listen, that before the cedars of our village shall have died of age, and the maples of the valley have ceased to give us sugar, the race of the corn-eaters will have destroyed the race of the flesh-eaters, unless the hunter should resolve to exchange his wild pursuits for those of the husbandman."

105. The plant amply rewards the labour and care bestowed on its cultivation. Only compare the dwarfish tuber of the wild potato in the Mexican mountains, with the gigantic tuber of the cultivated potato of our soil; the wild carrot root, no thicker than a quill, and hard and sapless, with the juicy, saccharine vegetable cultivated for the table; the sour crab-apple of our woods and hedges, with the delicious ribstone-pippin!

As an instance of the rich return which fruit-trees, for example, will give for the care and labour bestowed on them, we may be permitted to relate the following fact. During the Seven-Years' War, a poor sick French soldier was

left behind in *Wallerstädten*, a small village near *Darmstadt*. The kind villagers nursed the sick man, and he recovered his health and strength. Gratefully attached to the people who had acted so humanely by him, he made up his mind to pass his life among them, supporting himself by his labour. Being intrusted with the care of the village cattle, he observed that there was ample room on the common for many a useful tree. This determined him, at the season when the cattle were stabled, to make a journey to his own country, whence he carried on his back a number of young stems of good fruit-trees, which he planted on the common. He went repeatedly the same way for the same purpose, and planted gradually the whole common with trees, which form now a splendid orchard, yielding a considerable annual revenue to the community.

PARASITIC PLANTS.

106. Some plants grow without any attachment to the soil, united to other plants on which they feed, depriving them thus of a portion of their sap, and impairing accordingly, more or less, the vigour of their growth. Such plants are called *parasitic plants;* they are mostly united to the so-called *bast-layers* of the stem on which they are found. The most familiarly known one of the tribe is the *Misletoe*, which is frequently found growing on fruit-trees and forest-trees, and whose white berries yield a viscid matter like bird-lime. Many of the vegetable parasites are attached to the roots of other plants, as *Orobanche*, or *broom-rapes*, for instance; *Lathræa*, or *scale-wort*, and *Monotropa*, or *fir-rapes*. The various species of *Cuscuta*, or *dodder*, prove often peculiarly destructive to flax and clover.

DURATION OF THE LIFE OF PLANTS.

107. Whilst the existence of myriads of minute or microscopic fungi extends over a few brief hours only, many of the fungoid plants will live several days, or even weeks. The more highly organised plants are divided, according to the greater or less duration of their existence, into *annual*, *biennial*, and *perennial* plants. Some of the latter live to a great age.

From the number of annual rings or layers in several trees, it has been clearly shown that the trees in question, and which continue still in vigorous growth, are upwards of 2,000 years old. Nay, the age of certain specimens of the *Baobab* of Senegal, or monkey-bread-tree (*Adansonia digitata*), is estimated at 6,000 years!

Generally, though not universally, the girth of the trunk corresponds to the age of the tree. A large girth indicates a great age. While our red-pine attains a height of from 160 to 180 feet, and a diameter of 6, there are palms which, without being thicker, reach to the immense altitude of 250 feet. There are many of the winding plants of South America which have stems only about an inch thick, and which reach the astonishing length of 1,500 feet. On Mount Etna there are some ancient chestnut trees that measure from 60 to 80 feet in girth.

An elm, at Worms, called the Luther tree, is 116 feet high, and 35 feet in circumference. Its age may be from 600 to 800 years. The baobab trees just mentioned, have a diameter of from 27 to 30 feet, with a height by no means in proportion (60 to 80 feet).

Some seeds lose their vitality soon, others retain it for a long time. Thus, some barley seeds were found to germinate, which had been discovered in a tomb supposed to date from the period of the irruption of the Arabs into France, and accordingly about 1,000 years old. Nay, we have instances of living plants produced from seeds found in the catacombs of Egypt, and which could not possibly be less than 2,000 years old.

DISTRIBUTION OF PLANTS OVER THE GLOBE.

108. The surface of the earth is very unequally covered with vegetation. As we approach the Arctic regions, we find plants gradually diminishing both in number and size; the lofty pine of our forests is *there*—in the inhospitable wastes of high latitudes—seen dwindled to the dwarfish proportion of a stunted shrub; farther on towards the poles, lichens and mosses alone deck the frozen surface; and in the highest latitude—the regions of eternal snow and ice—all traces of vegetation are lost. In the tropical regions, on the other hand, we find a most profuse and luxuriant vegetation, putting forth gigantic leaves, the most gorgeous flowers, and the richest and most delicious fruit.

Most plants have a restricted range of distribution: many are confined to certain regions, or even to single localities. Imaginary lines may be drawn round the globe to indicate the limits of the regions of the olive, the vine, the maize, &c., &c. These imaginary lines do not run parallel with the equatorial line, as the mean temperature of a region may be considerably modified by local influences. (See Physics, § 150).

In the temperate climate of England many plants from Australia and Polynesia, which would perish from cold in Germany, grow in the open air, whilst the grape and peach which come to maturity in the latter country, rarely ripen here, as they require a higher summer temperature than our insular situation permits us to enjoy. The lofty mountains of the warm zones present at different altitudes the *floras** of the most dissimilar climates; whilst palms and orange-trees flourish at the base, their summit is decked with lichens, or capped with eternal ice and snow.

109. Nature has abundantly provided for the dissemination of plants within the limits of their natural regions. Wind, water, and animals, are instrumental in disseminating them. Many seeds are supplied with winged and feathery appendages, and are thus easily wafted about; others are provided with minute hook-appendages, whereby they fasten on the hairy skin of animals, and are thus conveyed to greater or less distances. The birds and the herbivorous quadrupeds are also active instruments in the dissemination of plants. Rivers, streams, and even the great ocean itself serve to transport seeds to distant regions.

Nevertheless, the flora of America and of Australasia was unknown to us before the discovery of those parts of the world; and every year brings the accession of new plants; and many of those which on their first introduction would appear to require the protection of the conservatory, get gradually accustomed to the climate, and even grow wild, as, for instance, the beautiful evening primrose, or night primrose (*Œnothera*), which was brought to Europe in 1614, and now grows freely on our meadows, and on the ridges of our fields; so also the Canadian flea-wort (*Erigeron*), which after the dis-

* By the *flora* of a country, we understand its native or indigenous vegetation.

covery of America, was accidentally brought over to Europe along with some rye, and forms now one of the most common weeds of our fields.

III. CLASSIFICATION OF PLANTS.

SYSTEMATIC BOTANY, OR TAXONOMY.

110. The Classification of plants is, like all other arrangement in classes, founded upon an *idea of likeness*. It is obvious that the *resemblances* selected to base the arrangements upon, must rest not upon vague generalities, but upon distinct and characteristic marks. For supposing, for the sake of illustration, we were to classify plants according to their size, into *herbs*, *shrubs*, and *trees*, we should have to place the willow, for instance, in every one of these three categories, since it occurs on the mountains as an *herbaceous* plant, and in the plains both as a shrub and as a tree.

For the groundwork of the system of classification which universally obtains at present, we are indebted to *Linnæus*, a Swede, born in 1707, and who will always occupy a high place among the most distinguished naturalists. In his classification of plants, *Linnæus* followed two different methods. In the one, he based his division of plants in classes and orders, upon certain peculiarities in the floral organs. This system, being thus founded on characters taken from certain parts of the plant only, without reference to others, and having something artificial in it, has for that reason been termed, the *artificial* system, but it is now more generally known as the *Linnæan* system. In the other method, he arranged the plants according to certain general resemblances and affinities, in natural orders or families. This system, which is known as the *natural* system, has subsequently been much improved by *Jussieu*, Curator of the Jardin des Plantes, in Paris, and more recently by *Decandolle*, of Geneva, and *Dr. J. Lindley*, of London.

111. In botanic classifications, we use the term *species*, to designate a number of individnal plants, which, in all essential and unvarying characters, resemble each other more closely than they do any other plant; the term *genus* or *kind*, to designate an assemblage of nearly allied species, agreeing with one another in general structure and appearance more closely than they do with any other species. Here too it must be obvious, that while all parts of the plant may furnish *specific* characters, the character of the *genera* are taken exclusively from the parts of fructification.

In the name of a plant, both the *genus* and the *species* are given. The name designating the genus, is called the *generic* name of the plant, the one designating the species, the *specific* or *trivial* name. Thus, for instance, we have the genus *Viola*, which includes the species *Viola odorata*, sweet violet; *Viola canina*, dog violet; *Viola tricolor*, heart's-ease; and others.

It is necessary to give the Latin names of plants, as the common name differs not only in different countries, but even in different parts of the same country.

An assemblage or group of allied genera, agreeing in their general characters, though differing in their special conformation, is called an *order* or *family* of plants.

The sun-flower, the daisy, the aster, and the dahlia, are, for example, plants of different genera, but which all of them belong to the same order or family.

That all plants are divided into three *primary classes*, viz., *Dicotyledons*, *Monocotyledons*, and *Acotyledons*, has been stated already in § 28.

A proper degree of familiarity with the systematic classification of plants is of the very highest importance to the student. A successful pursuit of this branch of the botanical science presupposes a thorough knowledge of the structure and physiology of plants, and requires, moreover, the aid of attentive observation, and also some diligence in collecting and arranging plants.

THE ARTIFICIAL OR LINNÆAN SYSTEM OF CLASSIFICATION.

112. In this system plants are divided into 24 *classes;* twenty-three of these contain the *Dicotyledones* and *Monocotyledones* indiscriminately; the twenty-fourth class contains the *Acotyledones.*

The first twenty-three classes are founded on the number, position, relative lengths, and connection of the stamens. The twenty-fourth comprises the plants with inconspicuous flowers. Every class is subdivided again into several orders. This division depends, in the first thirteen classes, on the number of the styles; in classes XIV. and XV. on the nature of the fruit; in classes XVI. to XVIII. and XX. to XXII. on the number of stamens; in classes XIX. and XXIII. on the perfection of the flower. In class XXIV. the orders are formed according to natural affinities.

TABULAR VIEW OF THE LINNÆAN SYSTEM OF CLASSIFICATION.

A.—FLOWERS PRESENT (*Phanerogamia*).

I. Stamens and pistil in every flower (hermaphrodite).

1. Stamens free.

a. Stamens of equal length, or not differing in definite proportions.

Number of Stamens.	Class
1	Class 1. Monandria.
2	„ 2. Diandria.
3	„ 3. Triandria.
4	„ 4. Tetrandria.
5	„ 5. Pentandria.
6	„ 6. Hexandria.
7	„ 7. Heptandria.
8	„ 8. Octandria.
9	„ 9. Enneandria.
10	„ 10. Decandria.
11—19	„ 11. Dodecandria.
20 or more inserted on calyx	„ 12. Icosandria.
20 or more „ receptacle	„ 13. Polyandria.
b. Stamens of different lengths, two long and two short	„ 14. Didynamia.
„ „ four long and two short	„ 15. Tetradynamia.
2. Stamens united by filaments in one bundle	„ 16. Monadelphia.
„ „ in two bundles	„ 17. Diadelphia.
„ „ in more than two bundles	„ 18. Polyadelphia.
„ by anthers (compound flowers)	„ 19. Syngenesia.
„ with pistil on a column	„ 20. Gynandria.
II. Stamens and pistil in different flowers (unisexual)	
on the same plant	„ 21. Monœcia.
on different plants	„ 22. Diœcia.
III. Stamens and pistil in the same or in different flowers, on the same or on different plants	„ 23. Polygamia.
B.—FLOWERS ABSENT	„ 24. Cryptogamia.

TABULAR VIEW OF CLASSES AND ORDERS.

Classes.	Orders.		Examples.
I.—MONANDRIA . .	Monogynia . .	one style	Hippuris.
One stamen.	Digynia . . .	two styles	Callitriche.
II.—DIANDRIA . . .	Monogynia . .	one style	Syringa.
Two stamens.	Digynia . . .	two styles	Anthoxanthum.
	Trigynia . . .	three do.	. . .
III.—TRIANDRIA . . .	Monogynia . .	one style	Iris.
Three stamens.	Digynia . . .	two styles	Hordeum.
	Trigynia . . .	three do.	Holosteum.
IV.—TETRANDRIA . .	Monogynia . .	one style	Scabiosa.
Four stamens.	Digynia . . .	two styles	Gentiana.
	Trigynia . . .	three do.	. . .
V.—PENTANDRIA . .	Monogynia . .	one style	Borago.
Five stamens.	Digynia . . .	two styles	Fœniculum.
	Trigynia . . .	three do.	Sambucus.
	Tetragynia . .	four do.	Parnassia.
	Pentagynia . .	five do.	Linum.
	Polygynia .	six and more do.	Myosurus.
VI.—HEXANDRIA . .	Monogynia . .	one style	Lilium.
Six stamens.	Digynia . . .	two styles	Oxyria.
	Trigynia . . .	three do.	Rumex.
	Tetragynia . .	four do.	Alisma.
	Polygynia . .	many do.	. . .
VII.—HEPTANDRIA . .	Monogynia . .	one style	Trientalis.
Seven stamens.	Digynia . . .	two styles	. . .
	Trigynia . . .	three do.	. . .
	Heptagynia . .	seven do.	. . .
VIII.—OCTANDRIA . .	Monogynia . .	one style	Daphne.
Eight stamens.	Digynia . . .	two styles	Chrysosplenium.
	Trigynia . . .	three do.	Polygonum.
	Tetragynia . .	four do.	Paris.
IX.—ENNEANDRIA . .	Monogynia . .	one style	. . .
Nine stamens.	Trigynia . . .	three styles	. . .
	Hexagynia . .	six do.	Butomus.
X.—DECANDRIA . . .	Monogynia . .	one style	Pyrola.
Ten stamens.	Digynia . . .	two styles	Dianthus.
	Trigynia . . .	three do.	Silene.
	Pentagynia . .	five do.	Lychnis.
	Decagynia . .	ten do.	. .
XI.—DODECANDRIA . .	Monogynia . .	one style	Lythrum.
Twelve to nineteen stamens.	Digynia . . .	two styles	Agrimonia.
	Trigynia . . .	three do.	Reseda.
	Pentagynia . .	five do.	. . .
	Dodecagynia . .	twelve do.	Sempervivum.

Tabular View of Classes and Orders—*continued.*

Classes.	Orders.		Examples.
XII.—ICOSANDRIA . . Twenty or more stamens inserted on the calyx.	Monogynia . .	one style	Prunus.
	Digynia . . .	two styles	Cratægus.
	Trigynia . . .	three do.	Sorbus.
	Pentagynia . .	five do.	. . .
	Polygynia . .	many do.	Rosa.
XIII.—POLYANDRIA . . Many stamens inserted on the receptacle.	Monogynia . .	one style	Papaver.
	Digynia . . .	two styles	Pæonia.
	Trigynia . . .	three do.	Aconitum.
	Tetragynia . .	four do.	. . .
	Pentagynia . .	five do.	Nigella.
	Hexagynia . .	six do.	. . .
	Polygynia . .	many do.	Ranunculus.
XIV.—DIDYNAMIA . . Two long and two short stamens. Labiate and Personate Flowers.	Gymnospermia .	four naked seeds	Lavandula.
	Angiospermia .	seeds in capsules	Linaria.
XV.—TETRADYNAMIA . Four long and two short stamens. Cruciferous Flowers.	Siliculosa . .	broad and short pod (silicula), and style	Capsella.
	Siliquosa . .	long pod (siliqua); stigma sessile	Brassica.
XVI.—MONADELPHIA . Stamens united in one bundle.	Pentandria . .	five stamens	Erodium.
	Enneandria . .	nine do.	. . .
	Decandria . .	ten do.	Geranium.
	Dodecandria . .	11–19 do.	Malva.
	Polyandria . .	many do.	. . .
XVII.—DIADELPHIA . . Stamens united in two bundles (one generally containing nine enclosed in a tube, and one free). Papilionaceæ.	Pentandria . .	five stamens (two above and three below.)	. . .
	Hexandria . .	six do. (three right, three left, or three above and three below.)	Fumaria.
	Octandria . .	eight do. (four above and four below, all united at the base.)	Polygala.
	Decandria . .	ten do. (one above and nine below, united in a cleft tube surrounding the ovary.)	Pisum, Trifolium, Genista.
XVIII.—POLYADELPHIA . Stamens united in more than two bundles.	Pentandria . .	five bundles (each bundle bearing five anthers = 25 stamens.)	. . .
	Dodecandria . .	twelve do. (each bundle bearing three anthers = 36 stamens.)	. . .
	Icosandria . .	many stamens in bundles, inserted on the calyx (20 stamens in bundles bearing an unequal number of anthers.)	Citrus.
	Polyandria . .	many do. in three, five, and nine bundles, inserted on the receptacle.	Hypericum.

Tabular View of Classes and Orders—*continued.*

Classes.	Orders.	Examples.
XIX.—SYNGENESIA . . Five stamens, filaments free, anthers united, flower monopetalous, florets united on a disk. Compositæ. In the first four orders only a common calyx. (See § 67, fig. iii.)	Polygamia æqualia, florets all hermaphrodite.	Lactuca.
	Polygamia superflua, florets of the disk hermaphrodite, those of the ray pistilliferous and fertile.	Aster.
	Polygamia frustranea, florets of the disk hermaphrodite, those of the ray neutral.	Helianthus.
	Polygamia necessaria, florets of the disk staminiferous, of the ray pistilliferous.	Calendula.
	Polygamia segregata, a common calyx including all the florets, and a separate involucre for each.	Echinops.
	Monogamia, anthers united, flowers not compound.	. . .
XX.—GYNANDRIA . . Stamens and pistil united.	Diandria . . . two anthers	Orchis.
	Triandria . . three do.	. . .
	Tetrandria . . four do.	. . .
	Pentandria . . five do.	. . .
	Hexandria . . six do.	Aristolochia
	Decandria . . ten do.	. . .
	Dodecandria eleven to nineteen do.	. . .
	Polyandria twenty or more do.	. . .
XXI.—MONŒCIA . . . Stamens and pistils in different flowers on the same plant.	Monandria . . one stamen	Arum.
	Diandria . . two stamens	Lemna.
	Triandria . . three do.	Carex.
	Tetrandria . . four do.	Urtica.
	Pentandria . . five do.	Amaranthus
	Hexandria . . six do.	. . .
	Heptandria . . seven do.	. . .
	Polyandria . more than seven do.	Quercus.
	Monadelphia . stamens united	Pinus.
	Syngenesia . stamens united by their anthers.	. . .
	Gynandria, stamens and styles united	. . .
XXII.—DIŒCIA . . . . Stamens and pistils in different flowers on different plants.	Monandria . . one stamen	Salix.
	Diandria . . . two stamens	. . .
	Triandria . . three do.	Ficus.
	Tetrandria . . four do.	Viscum.
	Pentandria . . five do.	Cannabis.
	Hexandria . . six do.	Loranthus.
	Octandria . . eight do.	Populus.
	Enneandria . . nine do.	Laurus.
	Decandria . . ten do.	. . .
	Dodecandria eleven to nineteen do.	Stratiotes.
	Polyandria many do.	. . .
	Monadelphia stamens united in one bundle.	Juniperus.
	Syngenesia stamens united by the anthers.	. . .
	Gynandria stamens and styles united.	. . .

Tabular View of Classes and Orders—*continued.*

Classes.	Orders.		Examples.
XXIII.—POLYGAMIA . . Stamens and pistil in the same or in different flowers, on the same or on different plants.	Monœcia, hermaphrodite, staminiferous, and pistilliferous flowers on the same plant.		Acer.
	Diœcia . .	on two plants	Fraxinus.
	Triœcia . .	on three plants	. . .
XXIV.—CRYPTOGAMIA . . Organs of fructification concealed (flowers inconspicuous.)	Filices . . .	Ferns	Aspidium.
	Musci . . .	Mosses	Spagnum.
	Hepaticæ . .	Liverworts	Marchantia.
	Lichenes . .	Lichens	Cetraria.
	Algae . . .	Seaweeds	Fucus.
	Fungi . . .	Mushrooms	Agaricus

113. With all its imperfections, the artificial system has this advantage, that the character on which it is founded is sufficiently conspicuous (that is, of course, with the plants in full flower) to render it generally easy to ascertain the class and order of a plant. At all events, it may serve as a useful artificial key, and as such may be combined advantageously with the natural system.

114. NATURAL SYSTEM (JUSSIEU'S).

Classes.			
I. Acotyledones		. . . .	1st Class.
II. Monocotyledones		Mono-hypogynæ (stamens hypogynous) . .	2nd „
		Mono-perigynæ (stamens perigynous)	3rd „
		Mono-epigynæ (stamens epigynous)	4th „
III. Dicotyledones.	Monoclines, flowers hermaphrodite.		
	Apetalæ (no petals)	Epistamineæ (stamens epigynous)	5th „
		Peristamineæ (stamens perigynous)	6th „
		Hypostamineæ (stamens hypogynous) . . .	7th „
	Monopetalæ (petals united).	Hypocorollæ (corolla hypogynous)	8th „
		Pericorollæ (corolla perigynous)	9th „
		Epicorollæ (corolla epigynous) — Synantheræ (anthers united) .	10th „
		Epicorollæ (corolla epigynous) — Chorisantheræ (anthers free) .	11th „
	Polypetalæ (petals distinct)	Epipetalæ (petals epigynous)	12th „
		Peripetalæ (petals perigynous)	13th „
		Hypopetalæ (petals hypogynous)	14th „
	Diclines, flowers unisexual, or without a perianth		15th „

This system, being likewise founded partly on individual organs, is also, to a certain extent, artificial; and, strictly speaking, every natural method of botanic classification must partake more or less of an artificial character, as many orders of plants merge so insensibly into others that their respective limits cannot be accurately or rigorously defined.

IV. DESCRIPTION OF PLANTS.

DESCRIPTIVE BOTANY.

115. The marvellous variety, both in form and structure, of the subjects of the vegetable kingdom may be inferred from the fact, that already above 100,000 species of plants are known, and every day adds to the number. However, this vast number of species is distributed over the whole surface of the globe, and a comparatively small number only falls to the respective share of different regions, countries, or localities. In Germany there are about 7,000 species of plants; the British Isles number considerably less.

Botanical works treat either of the universal Flora of the globe, or simply of the Flora of some particular region, country, or locality. Some of the best works on the botanical science are written in Latin, to make them practically useful to the learned of all nations.

Of the many works on the *Flora of Germany*, we may mention here *Koch's* Synopsis of the German and Swiss Flora, and the compendium of the German Flora by the same author; and also *Kittel's* work on the same subject. Among the local Floras of certain parts of Germany may be mentioned that of Frankfort-on-the-Maine, by *Fresenius;* of Baden, by *Gmelin;* of Würtemberg, by *Schübler*, and by *Martens;* of Hesse, by *Schnittspahn;* of the Rhine, by *Döll;* of Austria, by *Schultes;* of Silesia, by *Wimmer;* of Berlin, by *Schlechtendal;* of Prussia, by *Ruthe;* of Brunswick, by *Lachmann*, &c., &c.

Besides the English Flora by Sir J. E. Smith, which will always be regarded as *the* standard work on British botany, and the works of Balfour, Babbington, Irvine, and others, the following local Floras may be recommended:— Dr. Johnston's Flora of Berwick-on-Tweed; Leighton's Flora of Shropshire; Jones's of Devon; Murray's Northern Flora, unfortunately only a fragment, but a valuable relict, especially to such as knew the amiable author, who was prematurely cut off in the zealous discharge of the duties of his profession. Besides these there are various county catalogues of plants more or less complete, and the ancient local lists of Blackstone, Jacobs, Warner, &c., together with the interesting itineraries of Johnson, the precursor of all British local botanists.

To the English student of botany we recommend more particularly Balfour's masterly digest of the science (Manual of Botany).

The most practical, and, in fact, the only way likely to lead to the acquisition of true botanical lore, is to collect specimens of the various species of plants, and to compare them carefully and attentively with the description given of them in botanical works, and with other allied species.

The following is meant rather as a simple enumeration than a description of certain families of plants that come more particularly under our notice from their various uses in the great economy of life (in medicine, in the arts, &c.):—

SECTION I. PHANEROGAMOUS PLANTS.

A. DICOTYLEDONES.

The largest class in the vegetable kingdom. The plants included under it have a *cellular* and *vascular* system, the latter consisting partly of elastic

spiral vessels. The *leaves* are *reticulated.* The embryo has two or more opposite cotyledons.

Subclass I. THALAMIFLORÆ. (Flowers on the receptacle.)

116. RANUNCULACEÆ, the *Crowfoot family.* The numerous plants of this order belong almost exclusively to the 13th Class of the Linnæan system. They are all of them more or less acrid, and most of them are poisonous. Some are used in medicine; and a great many are cultivated in our gardens for their beautiful flowers.

The most remarkable of this order are, the genus *Ranunculus*, from which the order is named, and of which the *buttercup* (*ranunculus acris* and *auricomus*), is common on meadows, and the *poisonous crowfoot* (*ranunculus sceleratus*), in marshy localities; the *black hellebore;* the *Anemone;* the *Aconite* or *wolf's-bane;* the *larkspur* (*delphinium*); the *Columbine* (*Aquilegia*); the *Nigella;* the gorgeous *Peony.* The various beautiful species of *Clematis,* most of them climbing plants, belong also to this order.

117. NYMPHÆACEÆ, the *Water-lily family.* The white water-lily (*Nymphæa alba*), is well known as the ornament of our ponds and lakes. It is allied to the Egyptian water-lily or *Lotus-flower*, of which the seeds and roots are edible, and which are figured on Egyptian and Indian monuments.* The largest and most magnificent of aquatic plants, is the *Victoria regia*, or *Guinea water-lily*, with its immense white and rose-coloured flowers, more than a foot in diameter, and its gigantic leaves, from 12 to 20 feet in circumference.

118. PAPAVERACEÆ, the *Poppy family.* The most important plant of this family is the *common Poppy* (*Papaver somniferum*), which is widely cultivated in Turkey and in the East Indies, for the sake of the milky juice procured from the unripe capsules, and which possesses strongly-marked narcotic properties: the inspissate and concrete juice is known by the name of *opium.* The orientals use it largely as a means of intoxication. The ripe seeds of the poppy yield a bland and wholesome oil. Opium is a mixture of caoutchouc, resin, and several vegetable acids and bases, of which latter *morphia* is the most important. (Chemistry, § 128.)

The *common red poppy*, or *field poppy* (*Papaver rhœas*), grows wild in the fields; and Celandine (*Chelidonium majus*), is frequently seen by the roadside, near towns and villages.

119. CRUCIFERÆ, the *cruciferous* or *Cresswort family.* A large and well-characterised family, wholly included in the Linnæan class *Tetradynamia;* having six stamens, four long and two short. The number of the petals is four, which are arranged in form of a cross. Fruit a siliqua, or a silicula. All parts of the plant contain a pungent, sulphurous, volatile oil; and the seeds yield a copious amount of fixed oil. Many of our most common ordinary vegetables belong to the order, such as *Turnip* (*Brassica rapa*), *Cress* (*Lepidium*), *Radish* (*Raphanus*), *Cabbage* (*Brassica oleracea*), and its varieties, *crisped colewort*, *savoys*, *cauliflower*, *Brocoli*, *red Cabbage*, &c. Many of the Cruciferæ possess marked anti-scorbutic and stimulating qualities, as *e. g.* scurvy-grass (*Cochlearia officinalis*); the *Horse-radish* (*Cochlearia*

* Some botanists suppose the flower of *Nelumbium spavissum* to be the ancient Lotus of the Nile.

armorica), has irritant, and even vesicant properties. The seeds of *Sinapis nigra* furnish our table-mustard. Many ornamental plants also belong to this order, as *e. g. stock, wall-flower, rocket* (*lunaria*). *Woad* (*Isatis tinctoria*), yields a blue dye, which was formerly, before the introduction of indigo, in much greater request than it is now.

120. VIOLACEÆ, the *Violet family*. A small order composed chiefly of the numerous species of the genus *Viola*. Examples, the *sweet-scented violet* (*viola odorata*), the *heart's-ease* (*Viola tricolor*), and the *field violet* (*Viola arvensis*), which latter is given in infusion in certain diseases of the skin. The roots of the *Violaceæ* have emetic properties.

121. CARYOPHYLLACEÆ, the *Chickweed family*. Some of this family are showy garden flowers, as *e. g.* the numerous species of *pink* or *carnation* (*Dianthus caryophyllus*), and of *Lychnis*. The *soap-wort* plant (*Saponaria*), the bruised leaves of which make a lather with water, and the *Corn-cockle* (*Lychnis githago*), belong also to this order.

122. MALVACEÆ, the *Mallow family*. The plants belonging to this order yield an abundant supply of a viscid mucilage. The *common mallow* (*Malva sylvestris*), the *marsh mallow* (*Althæa officinalis*), and the *hollyhock*, (*Althæa rosea*), are employed medicinally, as demulcents and emollients.

But one of the most important plants of the order is the *cotton-plant* (*Gossypium*), indigenous in Africa, and in the East Indies, whence it has been transplanted successfully to America, the West Indian Islands, and even to the south of Europe. The cotton is composed of the hair surrounding the seeds, and which form in the carpels, as the seeds advance to maturity; we see a similar substance formed in the catkins of our poplars and willows, and in the capsules of *Epilobium* (French Willow-herb). It may be safely assumed that cotton constitutes the staple material of clothing for the great majority of mankind. The cultivation of the plant, and the transformation of the raw material into the manufactured article, afford employment to millions of men, women, and children, aided by some of the most ingenious machines and mechanical appliances ever devised by the human intellect.

123. BYTTNERIACEÆ, the *Byttneria* and *Chocolate family*, or *Cacao-tree tribe*. The *theobroma cacao*, which yields the *cacao beans*, is a native of Mexico. The beans, which form the chief ingredient in chocolate, contain a crystalline principle analogous to caffeine, and which is called *Theobromine*.

124. TERNSTRŒMIACEÆ, the *Tea family*. The most important plant of this order is the tea-shrub (*Thea sinensis*), a native of the Celestial empire. The quality of the tea depends in a great measure upon the district in which the tea grows, upon the season when the leaves are picked, and upon the mode in which they are prepared. Tea contains a crystalline principle analogous to caffeine, and which is called *theine*. A Russian ambassador to the Court of Pekin introduced tea first into Europe, about the beginning of the 17th century. The annual production of tea in China, is estimated at about 500,000,000 lbs. The genus *Camellia*, which is prized on account of its showy flowers, belongs also to this order. The *Camellia japonica*, or *Japan Rose*, forms one of the choicest ornaments of our conservatories.

125. AURANTIACEÆ, the *Orange family*. These dark-leaved trees of the south of Europe and other sunny lands, abound in almost every part with receptacles of a fragrant, bitter, volatile oil. Their beautiful yellow fruits contain citric acid, and many of them also sugar. The rind or pod of this

fruit, more particularly of the ripe fruit, contains a bitter aromatic substance. Examples, the *Citron* (*Citrus medica*), the *Lemon* (*Citrus limonum*), the *Orange* (*Citrus aurantium*), and the *Bergamot* (*Citrus limetta*).

126. ACERACEÆ, the *Maple family*. The maples furnish an excellent material for articles of furniture, pipe-bowls, &c., and are useful also as fuel. From the juice of the *Sugar maple* (*Acer Saccharinum*), sugar is manufactured in North America.

127. AMPELIDEÆ, or VITACEÆ, the *Vine family*. The principal plant of this order is the *Grape vine* (*Vitis vinifera*), a native of Persia, which is now, however, fully acclimatised in the whole of southern, and in part of central Europe.

128. LINACEÆ, the *Flax family*. The most important of this order is the *flax-plant* (*Linum usitatissimum*), from the inner bark of the stalk of which we procure the *flax*, next to cotton, the most important clothing material, and, upon the whole, superior to the latter, from its greater tenacity and power of absorbing moisture, and also from the use we make of it in the manufacture of paper. The cotyledons of the seeds of *linum usitatissimum*, yield the so-called *linseed oil*, which, on account of its siccative properties, is used in the preparation of colours and varnish.

129. FYGOPHYLLACEÆ, the *Guaiacum family*. The wood and the resin of *Guaiacum officinale* are used medicinally in cutaneous and syphilitic diseases. The wood of Guaiacum, commonly called *lignum vitæ*, is prized much on account of its hardness.

130. RUTACEÆ, the *Rue family*. The *garden rue* (*ruta graveolens*), contains a volatile oil of powerful odour. The *dittany* (*Dictamnus*), is one of the most beautiful of our wild flowers; the rich purple blossoms are said to emit a phosphorescent light in warm summer nights.

131. SIMARUBEÆ, the *Simaruba* and *Quassia family*. The intensely bitter *quassia wood*, which is extensively used in medicine, was formerly the product of the *Quassia amara* of Surinam, *Guiana*, and *Colombia*. Our present quassia of the shops is this wood of the *Simaruba*, or *Picræna excelsa* of Jamaica and other West Indian islands.

Subclass II. CALYCIFLORÆ. (Flowers on the calyx).

132. RHAMNACEÆ, the *Buckthorn family*. The black succulent berries of the *common*, or *purging buckthorn* (*Rhamnus catharticus*), contains a greenish juice, which, mixed with lime, and evaporated by degrees, forms the colour called *sap-green*. The charcoal of the *black elder* (*Rhamnus frangula*), is extensively used in the manufacture of gunpowder. The *Zizyphus jujube* supplies the fruit called *jujube*.

133. ANACARDIACEÆ, the *Cashew-nut family*. The plants of this order yield a number of resins, among which we will only mention here, *Mastic* or *Mastick*, the exudation of *Pistacia lentiscus*. The bark of the various species of *sumach* (*rhus*), abounds in *tannin*, and is largely used by the tanner and the dyer. The *poison-oak* (*Rhus toxicodendron*), contains a volatile acrid poison, which acts upon some persons with such virulence, that the mere handling of the leaves, nay, even a somewhat prolonged stay in the vicinity of the tree, suffices to cause in them a general inflammation and swelling of the skin. Allied to this family is the *walnut-tree* (*Juglans regia*), the fine-flavoured nuts of which yield a bland oil, which is used in

some countries as a substitute for olive oil. The wood of the walnut-tree is much used for articles of household furniture. *Juglans regia* is generally regarded by botanists as the head of a distinct family, the *Juglandacæ*, or *walnut family*.

134. AMYRIDACEÆ, the *Amyris family*. The *Balsamodendron myrrha* of Abyssinia, is generally looked upon as the source of the official myrrh.

135. LEGUMINOSÆ, the *Pea* and *Bean tribe*. This extensive and important order embraces many highly useful plants, some of which, as the Pea and Bean, are universally known as articles of food; the seeds of these latter abound in starch, and, besides, in phosphate of lime, and in azotised matter, and rank accordingly very high in the scale of nutritive plants. Examples, the *Bean* (*Phaseolus*), the *Pea* (*Pisum*), the *lentil* (*Ervum*), &c.; and as food for cattle, the various species of *clover* or *trefoil* (*trifolium*), *saintfoin* (*Onobrychis*), *Medick* and *Lucern* (*Medicago*). The *Melilot* (*Melilotus*) is used on account of its pleasant smell, as an ingredient in the making of green cheese; it is also used in the dry state to scent snuff.

To the arts, this order furnishes some of the most important dyes, and more especially the indigo, the most beautiful and fastest of all vegetable colours. The indigo of commerce is formed from various species of *Indigoferæ*, more particularly from *Indigofera tinctoria*, and *Indigofera cærulea*. Most of our indigo comes from the East Indies; it is prepared by macerating the branches of the plant in water; this brings on decomposition: a green scum rises to the surface of the liquid, the latter turns yellow and turbid, and acquires afterwards a blue colour, and deposits a blue sediment, which is then collected, pressed into square cakes, dried, and packed for exportation.

The *hæmotoxylon campeachianvm*, furnishes the Logwood or Campeachy wood, which is used as a dye (blue, violet, and black). The *Cæsalpinia echinata* gives the Pernambuco wood, which serves as a red dye.

Many of the *Leguminosæ* have medicinal qualities, as *e. g.* the various species of *Acacia*, which yield the gummy substances known as *Gum Arabic*, *Gum Senegal*, *Barbary Gum*, *East Indian Gum*, *Babool Gum*, and some other varieties; the various species of *Cassia*, which supply the senna of the shops; the *St. John's bread-tree* or *Carob-tree* (*Ceratonia siliqua*); the *Tamarind-tree* (*Tamarindus indica*); the *Liquorice* (*Glycirrhiza glabra*); the various species of *Astragalus*, which yield the Gum Tragacanth; the *Myroxolon peruiferum*, and *toluiferum*, which respectively yield the balsams of Peru and Tolu. Many of the plants of the Pea and Bean tribe, more particularly of the suborder *Papilionaceæ*, have beautiful showy flowers, as *e. g. Robinia*, *Laburnum*, *Citysus*, *Clianthus*, *Lupinus*, &c.

136. ROSACEÆ, the *Rose family*. Another extensive and highly important order. Though there exist wide differences between the many genera and species constituting this order, still, an attentive study of the flowers of the different genera will show that the distinctive name of the family has properly been derived from the *Rose*, the queen of flowers.

The celebrated oil or *attar* of roses, is prepared from the petals of *Rosa centifolia*, and its varieties; the *damask-rose* (*Rosa damascena*), the *musk-rose* (*Rosa moschata*) and others.

Culture has produced an extraordinary number of species and varieties,

not only of the Rose, but also of most of those plants of the order which yield edible fruits, such as the *Plum-tree* (*Prunus domestica*), the *Apricot*, the *Peach* (*Amygdalus persica*), the *Cherry* (*Cerasus*), the *Pear* (*Pyrus*), the *Apple* (*Pyrus malus*), the *Quince* (*Pyrus cydonia*), the *Strawberry*, the *Raspberry*, the *Bramble*, &c. The berries of the *Blackthorn* or *Sloe*, (*Prunus spinosa*), are tart and astringent. The leaves of the *Cherry laurel* (*Prunus laurocerasus*), the seed of the *bitter almond* (*Amygdalus amara*), and the seeds of all the plants of the suborders *Amygdaleæ* and *Pomeæ*, contain hydrocyanic acid. The *Sorb-apple-tree* (*Sorbus*), is often used to plant avenues; and the *Hawthorn* (*Cratægus*), to plant hedges.

137. Myrtaceæ, the *Myrtle family*. The plants of this order are chiefly natives of warm countries; still, there are many of them that are found in more temperate regions. In our own climate, we cultivate some of them as ornamental plants, especially the common *Myrtle* (*Myrtus communis*), whose shining green leaves and pure white blossoms look so charming in the bridal wreath.

Many of the plants of this family yield an aromatic volatile oil. The *Cloves* of commerce are the flower-buds of *Caryophyllus aromaticus;* the leaves of *Melaleuca minor*, yield the volatile oil of *Cajeput; Pimento*, or *Allspice*, is the baccate fruit of *Eugenia pimento*, or *Myrtus pimento*. The *Guavas* and *Rose-apples* are pulpy edible fruits, the former the produce of various species of *Psidium*; the latter of various species of *Eugenia*.

138. Cucurbitaceæ, the *Cucumber family*. This order is characterised by its large fruit. It contains the *Gourd* or *Pumpkin* (*Cucumis*), or (*Cucurbita pepo*), the *Cucumber*, the *Melon*, the *Colocynth*, the *White Briony*, &c.

139. Cactaceæ, the *Cactus* or *Indian Fig family*. The plants of this order are chiefly natives of the tropical parts of America. They are remarkable for their succulence, and the peculiar angular or flattened shape of their stems; the leaves are usually absent, and replaced by numerous, and often very dangerous, spires or prickles. However, most of these vegetable monstrosities have remarkably showy flowers; some species of Cactus are acclimatised in the south of Europe. Many plants of the order bear edible fruit, as *e. g.*. *Cactus opuntia*, or *Opuntia vulgaris*, the fruit of which is known under the name of *Prickly Pear*. The *Opuntia cochinellifera*, and some other species, afford food to the cochineal insect. The acidulous juice of the fruit of some species, makes them a welcome sight to the traveller in the hot and dry regions where they grow. The Cactus plants serve also as fuel, and in the formation of impenetrable hedges. For their showy flowers we cultivate them in our hot-houses, more especially the *Cactus Cereus*, *C. flagelliformis*, *C. grandiflorus*, and *C. speciosus*.

140. Grossulariaceæ, the *Gooseberry* and *Currant family*. This small order contains the various kinds of Gooseberry (*Ribes grossularia*), and Currant (*Ribes rubrum* and *nigrum*).

141. Umbelliferæ, the *Umbelliferous family*. All the plants of this order have five stamens, and belong accordingly to the class *Pentandria* of the Linnæan system. They are characterised by their variously-divided leaves, and umbellate involucrate flowers. The seeds are small, and, for the most part, abound in volatile oil, which makes them useful as spices and

in medicine. Such are, for instance, *Caraway seeds*, from *Carum carvi; Fennel*, from *Fœniculum vulgare; Anise*, from *Pimpinella anisum; Coriander*, from *Coriandrum sativum; Water-fennel*, from *Phellandrium aquaticum*; *Dill*, from *Anethum graveolens; Chervil*, from *Anethum cerefolium.*

The succulent saccharine root of some species is used as an article of food. Among such esculent species may be noticed—the *Carrot* (*Daucus carota*); the *Celery* (*Apium graveolens*); the *Parsnip* (*Pastinaca sativa*); the *Parsley root* (*Apium petroselinum*).

But the order contains also several poisonous species, such as *Hemlock* (*Conium maculatum*), and *Fool's parsley* (*Æthusa cynapium*), and which, unfortunately, from their resemblance to some of the edible species, are liable to be mistaken for the latter—mistakes which have not unfrequently led to fatal accidents; thus the roots of hemlock have been mistaken for parsnips, and the leaves of hemlock and of fool's parsley, for the common parsley or for chervil.

We will therefore give here a description of these two poisonous plants. The hemlock has a round hollow stem, from three to four feet high, and dotted with purple spots. The leaves are smooth, tripinnate; the leaflets, lanceolate, serrate, with the little teeth at the margin running out into a fine white hair point. The involucre of the umbel consists of from one to five bracts; the umbellules have pendulous involucels consisting of three bracts. The flowers are small and white; the fruit is oval; each hemicarp is traversed by five indented longitudinal ridges. The whole plant has a disagreeable mouse-like odour when it withers, or when it is rubbed between the fingers.

The parsnip differs from the hemlock by its yellow flowers, and the absence of involucre and involucels. With parsley, hemlock can hardly ever be confounded after the stem has made its appearance. The small leaflets of parsley are oval, incised, and dentate; rubbed between the fingers, they have an agreeable aromatic odour.

The *Fool's parsley* has bipinnate leaves, with small leaflets. The umbel has no involucre, but the umbellules are provided with pendulous involucels consisting of three bracts. The fruit is spherical, each hemicarp is traversed by five thick longitudinal ridges.

This plant (Fool's parsley) often grows in gardens, and might be mistaken for chervil or parsley; however, as its leaflets are smaller than the chervil and parsley leaves, and are, moreover, inodorous, a little examination will suffice to guard against a mistake of the kind.

The *Water hemlock* or *Cowbane* (*Cicuta virosa*), is still more poisonous than hemlock and fool's parsley; but growing, as it does, in stagnant waters, and not in gardens and fields, the danger from it is less.

The symptoms of poisoning by hemlock are a feeling of dulness and tension in the head, vertigo, delirium, and partial paralysis, with convulsive twitches. When inadvertently taken, vomiting should be induced, by the administration of warm water mixed with oil—a general remedy in cases of poisoning which may be had recourse to in most cases until the arrival of a medical man.

Some of the *Umbelliferæ* of Persia and Affghanistan yield milky juices, which concrete into a fetid gum-resin (Chemistry, § 145), as *e. g. Ferula*

asafœtida, which yields the *asafœtida* of the shops; and *Dorema ammoniacum*, which furnishes the *Gum-ammoniac.*

Subclass III. COROLLIFLORÆ.

142. CAPRIFOLIACEÆ, the *Honeysuckle family.* The various species of *woodbine* (*Lonicera caprifolium*), are great favourites for covering arbours, and for ornamenting verandahs. The flowers and berries of *Elder* (*Sambucus nigra*), have long been an esteemed soporific; *Snowball* (*Viburnum*), is one of our most ornamental shrubs.

143. RUBIACEÆ, the *Madder* and *Peruvian Bark family.* The most important of this order is the genus *Cinchona*, the various species of which furnish the Peruvian or Jesuit's bark. The Cinchona-tree seems to be confined to Peru, Columbia, and Bolivia. Peruvian bark was first brought to Europe towards the end of the 17th century, and was at that time estimated at and paid for almost its weight in gold. The Quinine of the Pharmacopœia, the most effective specific known against intermittent fever, is prepared from Peruvian bark. *Cephaëlis Ipecacuanha*, yields the Ipecacuan of the Pharmacopœia, the emetic most commonly given. But the most important plant of the family is the *Coffee-tree* (*Coffea arabica*), originally a native of Africa, but transplanted thence to Arabia, and to the East and West Indies. Coffee forms an important item in European imports. The first coffee-house was established in Constantinople in 1554; London, 1652; Marseilles, 1671. The annual production of Coffee is estimated at present at 500,000,000 lbs. Coffee contains a bitter crystalline principle called *Caffeine*, and which is equally found in Tea and Cocoa.

Madder (*Rubia tinctoria*), furnishes the fastest of our red dyes, the celebrated *Turkey-red.* The *galium*, which grows in our hedges, sticks to the clothes of man, and to the woolly covering of animals. The pretty *Woodruff* (*Asperula odorata*), is used in the preparation of the "*Maiwein*," a spring beverage which is a great favourite with the people on the banks of the Rhine.

144. VALERIANACEÆ, the *Valerian family.* The *Field salad*, or *Lamb's Lettuce* (*Fedia* or *Valeriana alitoria*), is one of the most welcome winter plants. The root of the *common Valerian* (*Valeriana officinalis*), is well known for its medicinal uses; it has a peculiar strong odour, very agreeable to cats, but the very reverse to the somewhat more fastidious sense of smell of man.

145. DIPSACACEÆ, the *Teazel family.* The most important plant of this small order is the *Fuller's teazel* (*Dipsacus fullonum*), the heads of which on account of their spiny bracts, are used in dressing cloth. The plants of the genus *Scabious* (*Scabiosa*), adorn our meadows and gardens.

146. COMPOSITÆ, the *Composite family.* (Composite flowers, see fig. 112). This is one of the largest families in the vegetable kingdom. It is subdivided into three suborders, viz., *Cynarocephalæ*, *Corymbiferæ*, and *Cichoraceæ.*

a. CYNAROCEPHALÆ, the *Artichoke tribe.* The leaves of the *blessed thistle* (*Carduus benedictus*), and the *Carline thistle* (*Carlina*), are used in medicine on account of their bitter principle, but much less so now than formerly. The *Corn flower* (*Centaurea cyanus*), is much admired for the beautiful blue of its petals; the *Burdock* (*Arctium lappa*), is familiarly

known from the tenacity with which the *bur* or *clot-bur* sticks to clothes, &c. The young succulent receptacles of the *Artichoke* (*Cynara scolymus*), are eaten. The dried flowers of *Carthamus tinctorius*, constitute the so-called *safflower* or *zaffer*, from which a pink dye is prepared.

b. CORYMBIFERÆ, the *Corymb-bearing tribe.* Of the plants of this tribe employed in medicine, we notice *Milfoil* (*Achillea millefolium*); *Chamomile* (*Anthemis nobilis*), distinguished from the baser sort by its hollow conical disk, and its pungent aromatic smell; the *Mountain arnica, Mountain tobacco*, or *Leopard's bane* (*Arnica montana*); the *elecampane* (*Inula Helenium*); the *Coltsfoot* (*Tussilago farfara*), the yellow flowers of which appear early in spring, whereas the leaves make *their* appearance only late in summer; the *Tansy* (*Tanacetum vulgare*), and the *Wormwood* (*Artemisia absinthium, Absinthium officinale*, and *A. vulgare*), contain an aromatic volatile oil, possessed of powerful anthelmintic properties. The *Artemisia absinthium* is remarkable for its intensely bitter taste.

The *Asters* of China (*Starwort*), the *Dahlias* of Mexico, and the stately *Sunflower* (*Helianthus*), are among the most ornamental of our garden plants. The roots of the *Girasole artichoke* (*Helianthus tuberosus*), are used as substitutes for potatoes. The seeds of *Madia sativa* yield a bland oil. Finally, we must not pass over here the *Daisy* (*Bellis*), the sweet ornament of our meadows; and the *everlasting plant* (*Gnaphalium*), of which our neighbours, the Germans and French, make funeral wreaths.

c. CICHORACEÆ, the *Cichory tribe.* This suborder is characterised by its ligulate florets. Most of the plants contain a bitter milky juice. Examples, the *common salad, lettuce* (*Lactuca sativa*), the *wild* or *poisonous lettuce* (*Lactuca virosa*); the *wild Succory* or *Chicory* (*Cichorium Intybus*); the *Endive* (*Cichorium Endivia*). The *Dandelion* (*Leontodon taraxacon*, or *taraxacum dens leonis*), is used medicinally. *Scorzonera* was once famous as a pot-herb.

147. ERICACEÆ, the *Heath family.* The *common heather* or *Ling* (*Calluna* or *Erica vulgaris*), is familiarly known. Most of the plants of the heath family are natives of Africa, though found also in Europe, America, and Asia. They are remarkable for their pretty globate, urceolate, and campanulate flowers. The heath plants frequently constitute almost the sole vegetation on barren sandy tracts, where they afford an abundant supply of honey to the bees. The *Alpine rose* (*Rhododendron*), adorns the summit of lofty mountains. The exotic *Rhododendrons* and *Azaleas* form the great ornaments of our lawns in early summer.

148. VACCINIACEÆ, the *Cranberry family.* This order is closely allied to the preceding. The *Cranberry* is the fruit of *Vaccinium oxycoccus*, and *V. macrocarpum;* the *red Whortleberry* or *Cowberry*, of *Vaccinium vitis-ideæ;* the *bilberry*, of *Vaccinium myrtillus.*

149. JASMINACEÆ, the *Jasmin* or *Jessamine family.* Many of the plants of this order have fragrant flowers, as, *e. g.* the sweet-scented *Jessamine.* The well-known Spanish fly is found only on plants of this and the next family.

150. OLEACEÆ, the *Olive family.* The most important plant of this family is the famous *Olive-tree* (*Olea europæa*), the pride of Italy and Greece, and the symbol of peace; the fleshy pericarp of the olive yields by

expression the well-known olive oil, the finest sorts of which come from Provence and Florence. Several species of *Ornus*, more particularly *O. rotundifolia* and *O. europæa* (*Manna ash* or *Flowering ash*), yield a sweet exudation called *Manna*. The common *Privet* (*Ligustrum vulgare*), and the various species of *Lilac* (*Syringa*), have fragrant flowers.

151. ASCLEPIADACEÆ, the *Asclepias family*. The plants of this order are used in medicine on account of their acrid, purgative, emetic, and diaphoretic properties. Examples, the *Butterfly-weed*, or *Pleurisy-root* (*Acclepias tuberosa*), which is used as a cathartic and diaphoretic; the *Hemidesmus indicus*, of which the fragrant waters are used in Madras as a substitute for sarsaparilla, and many others.

152. APOCYNACEÆ, the *Dogbane family*. Many of the plants of this order are poisonous, as *e. g.* the common *Oleander* (*Nerium oleander*). The *Periwinkles* (*Vincas*) are astringent and acrid.

153. LOGANIACEÆ, the *Logania family*. The plants of this order are highly poisonous; they inhabit chiefly tropical and warm climates. As an example, we notice here the genus *Strychnos*, and its varieties, *Strychnos nux vomica*, the *Poison-nut* or *Koochla*, the seeds of which contain the alkaloids Strychnia and Brucea, both, but more particularly the former, highly poisonous (Chemistry, § 123); *Strychnos Ignatia*, or *Ignatia amara*, the *St. Ignatius' bean*, of which the seeds also contain Strychnia; *Strychnos Tieuté*, the source of the famous Java poison, *Upas tieuté*.

154. GENTIANACEÆ, the *Gentian family*. An order of plants characterised by the intense bitterness of all parts, but more especially the roots. The *Gentiana acaulis*, and the *Gentiana verna*, both Alpine plants, are remarkable for their showy blue flowers. The *Gentiana lutea* has showy yellow flowers; the roots of the latter plant constitute the medicinal gentian. As a substitute for the latter, we use the flowering cymes of the common Centaury (*Erythræa centaurium*), and the leaves of the Buck-bean or Marsh-trefoil (*Menyanthes trifoliata*).

155. CONVOLVULACEÆ, the *Convolvulus* or *Bindweed family*. This small order contains the *hedge* and the *field Convolvulus* (*Convolvulus sepium* and *C. arvensis*); and the *Jalap-plant* (*C. Jalapa*), of which the root-stock contains a resin possessed of medicinal properties. The *Batatas edulis*, or *Convolvulus Batatas*, yield the sweet potato, which is used as an article of food in tropical countries.

156. BORAGINACEÆ, the *Borage family*. The plants of this order have terete stems, rough leaves, gymnopetalous 5-cleft corollas, with five stamens. They contain mucilage, and some of them nitrate of potassa, on which account they, and more especially *Borage* (*Borago officinalis*), require the presence of that salt in the soil on which they grow (see § 89). Among the more common species may be mentioned the *stone-crop*, or *Gremil* (*Lithospermum maritimum*); the *Bugloss* (*Anchusa*); the *Alcanna* or *Alkanet* (*Anchusa tinctoria*), which supplies the alkanet-root used as a reddish-brown dye; the *adder's wort* or *viper's bugloss* (*Echium*) and the *Forget-me-not* (*Myosotis palustris*).

157. SOLANACEÆ, the *Nightshade family*. The plants of this important order are characterised by their monopetalous 5-cleft rotate corolla, with five stamens. Most of them have narcotic properties, developed in some to a

most poisonous degree, but obscured in others by the presence of starchy and nutritious matter. The narcotic properties are generally most strongly prominent in the roots and seeds.

As poisonous plants of the order, we mention: the *Thorn-apple* (*Datura stramonium*); the *Henbane* (*Hyoscyamus*); the *Deadly-nightshade* or *Dwale* (*Atropa belladonna*), which often attracts children by its shining, dark brownish-black berries. The *Common nightshade* (*Solanum nigrum*), and the *Bitter-sweet* or *Woody-nightshade* (*Solanum dulcamara*), are somewhat less dangerous. *Datura arborea* is known as an ornamental plant by its long funnel-shaped flowers.

Tobacco (*Nicotiana*) partly loses its narcotic properties by drying, and by the manufacturing processes of maceration, &c. This plant, which forms now a staple article of commerce and consumption, was first brought from America in 1540.

To the same quarter of the world we are indebted for the *Potato* (*Solanum tuberosum*), which was first brought to Europe in 1586, by Sir Walter Raleigh, but has been extensively cultivated in our quarter of the globe only since about a hundred years ago. This valuable esculent being exceedingly prolific, and growing even in the poorest sand-soils, the danger of severe famine is considerably lessened thereby. Potatoes that have put forth sprouts and shoots in cellars and pits, are injurious to the health. Frozen potatoes may be rendered eatable again by putting them for a time in cold water; when a crust of ice has formed on the water, the potatoes are taken out, put into the cellar, and consumed as speedily as possible. In wet seasons, the proper quantity of farinaceous matter is not produced in the tubers, which renders them more prone to rot. The cause of the peculiar disease which has visited the potato since 1844, remains still in obscurity.

To the family of the Solanaceæ belong also the *Egg-plant* (*Solanum oviferum*) and the *Love-apple* (*Solanum Lycopersicum* or *Lycopersicum esculentum*), both ornamental plants. The fruit of the latter, the *Tomato*, or *Love-apple*, is eaten, more particularly in South America. The fruit of the *Peruvian winter cherry* (*Physalis Peruviana*) is also eaten. The fruit of the different species and varieties of *Capsicum* supplies the well-known *Cayenne pepper* and the *Chillies*.

158. SCROPHULARIACEÆ, the *Figwort family*. Among the species of this order we mention: the *Figwort* (*Scrophularia*); the *Pedicularis*; the *Eyebright* (*Euphrasia*); the *Great mullein* (*Verbascum thapsus*), the emollient and slightly narcotic woolly leaves of which are occasionally used in certain pectoral affections; and the most important of the medicinal plants of the order, the *Fox-glove* (*Digitalis purpurea*), with its beautiful red flowers. Some of the species of *Linaria* and *Calceolaria* are used for dyeing.

159. LABIATÆ, the *Labiate family*. The numerous species of this family are characterized by their labiate, ringent, or personate flowers, with four stamens, two long and two short. Most of them abound in aromatic volatile oil; many are used as grateful condiments; others find application in medicine. Ex., *Mint* (*Mentha*); *Balm* (*Melissa officinalis*); *Rosemary* (*Rosmarinus officinalis*); *Thyme* (*Thymus*); *Wild marjoram* (*Origanum vulgare*); *Sweet marjoram* (*Origanum majorana*); *Basil* (*Ocymum*); *Hyssop* (*Hyssopus*

officinalis); *Sage* (*Salvia officinalis*); *Savoury* (*Satureia*); *Lavender* (*Lavendula vera*), &c. &c. Among the non-aromatic plants of this order we will only mention the *Dead nettle* (*Lamium album*).

Subclass IV. MONOCHLAMYDEÆ. (One-cloaked.)

Section A. *Angiospermæ.* (Seed contained in an ovary.)

160. CHENOPODIACEÆ, the *Goosefoot family.* On the sea-shore, and in the vicinity of saline springs, we find the *Salt plants* (*Holophytes*), but more especially the species *Salsola* and *Salicornia*, which yield soda upon their combustion, and which were formerly of much greater importance than they are now, when we derive most of the soda we want from common salt. (See Chemistry, § 73.) The various species of *Goosefoot* (*Chenopodium*), grow freely on rubbish heaps. Many of the plants of this order are used as esculent pot herbs, as *e. g.* *Spinage* (*Spinacea oleracea*), *Garden orach* (*Atriplex hortensis*). Highly important, in an agricultural and economical point of view, are the several varieties of *Beet* (*Beta*), as the *Beet root*, and the *Field-beet* or *Mangold-wurzel* (*Beta campestris*).

161. POLYGONACEÆ, the *Buckwheat family.* The fruit of the *Buckwheat*, (*Polygonum fagopyrum*, or *Fagopyrum esculentum*), and of other species of buckwheat is used for food. Buckwheat is cultivated in some northern countries, where it grows on the very poorest soil. The plants of the genus *sorrel* or *dock*, contain oxalic acid, as *e.g.* the *Wood sorrel* (*Oxalis acetosella*), the common sorrel (*Rumex acetosa*), the *Field sorrel* (*Rumex acetosella*), &c. One of the most important of the order is the famous *Rhubarb plant* (*Rheum*), which grows on the Altai mountains, in Siberia, Thibet, North of China, and on the Himalayan range. Rhubarb is one of our most valuable medicinal agents; it comes to us chiefly through Russia.

162. LAURACEÆ, the *Laurel family.* The plants of this family are chiefly natives of the tropical regions of Asia and America. Most of them are aromatic and fragrant. Examples—the true *Cinnamon tree* (*Laurus Cinnamomum*), the bark of which constitutes the fine Ceylon cinnamon of commerce; and the *Cassia tree* (*Laurus Cassia*), which supplies the *Cassia lignea*, or Cassia bark of commerce. Cinnamon oil is prepared from the former, Cassia oil from the latter. The *Victor's laurel* (*Laurus nobilis*), not only supplies wreaths for conquerors and poets, but its leaves serve as grateful condiments, and the concrete green oil expressed from the berries (the oil of bays), is used in medicine. The *Camphor tree* (*Laurus camphora*), furnishes the camphor, which is extensively used in medicine, and as a preservative against the ravages of moths and other insects.

163. MYRISTICEÆ, the *Nutmeg family.* The most important plant of the order is the *Nutmeg tree* (*Myristica officinalis seu moschata*), which furnishes the *nutmeg* (the fruit), and the *mace* (the *arillus*, or additional covering to the seed). By expression, nutmegs are made to yield a concrete oil, called *Adeps myristicæ.* The beautiful *Tulip tree* (*Liriodendron tulipifera*), is, by some botanists, classed with the *Myristiceæ*, by others, and perhaps with greater reason, with the *Magnolia family.*

164. THYMELÆACEÆ, the *Daphne family.* The most common plants of the order are the *Spurge laurel* (*Daphne laureola*), and the *Mezereon* (*D.*

Mezereum). The bark of the Daphne plant is acrid and irritant; when applied externally, it acts as a vesicant. The beautiful peach-colored flower of Mezereon makes its appearance as early as March.

165. ARISTOLOCHIACEÆ, the *Birthwort family*. The plants of this order are generally bitter, tonic, and stimulant; some are acrid. Many of them are climbers. Some serve as ornamental plants, as *e.g.* the *Pipe tree* (*Aristolochia Sipho*), with large cordate leaves, and pipe-bowl shaped flowers; the *Virginian snakeroot* (*Aristolochia serpentaria*), and the *Hazel wort* (*Asarum Europæum*), are used in medicine.

166. EUPHORBIACEÆ, the *Spurge family*. With few exceptions, the numerous plants belonging to this order contain a juice which, applied to the skin, is caustic and vesicant, and taken internally, acts as a strong poison. The most familiarly known species of the order is the *Spurge* (*Euphorbia*). The root of the *Manchineel* (*Hippomane manchinella*), is highly poisonous in the raw state, but is rendered perfectly innocuous and eatable by boiling or roasting. The same is the case with the root of the *Cassava* or *Manioc plant* (*Janipha manihot*). The starch procured from these two roots is the *Tapioca* of commerce; in the West Indies it forms a staple article in the dietary of the negroes.

Croton oil, one of the most violent drastics known, is obtained by expression from the seeds of *Tiglium croton*. The well-known mild purgative, *Castor oil*, is expressed from the seeds of *Ricinus communis* (*Palma christi*). The wood of the *Box-tree* (*Buxus sempervirens*), is much used for wood-engraving, on account of its superior density and hardness. The milky sap of several American trees of this order, and more particularly of *Siphonia elastica*, contains much caoutchouc, and supplies the bottle India-rubber.

167. URTICACEÆ, the *Nettle family*. Many of the plants of this order supply valuable fibres for textile fabrics, as *e.g.* the *Hemp plant* (*Cannabis sativa*), of which the seeds yield also a greenish oil; the *Stinging nettle* (*Urtica*), the fibrous bark of which is made into nettle cloth. The pain caused by the stinging hairs of the nettles of our climate is as nothing compared to the fearful effects produced by some of the East Indian species of this plant. The *Hop plant* (*Humulus lupulus*), contains a bitter aromatic principle, which imparts to beer its grateful flavour. The hemp plant also contains a slightly aromatic, but at the same time narcotic principle; the variety *Cannabis Indica* is used in India to produce intoxication. One of our most useful trees, the *English* or *small-leaved Elm* (*Ulmus campestris*), belongs to the nettle family.

Many plants of the *Artocarpeæ* or *Bread-fruit tribe*, a distinct section of the nettle family, produce amylaceous fruit, which constitutes an important article of food in tropical countries; the most important tree of this tribe is the *Artocarpus incisa*, or *Bread-fruit tree* of the South Sea Islands.

The *Fig-tree* (*Ficus carica*), and the *Mulberry-tree* (*Morus nigra*), of the suborder *Moreæ* (*Mulberry tribe*), are highly prized for their delicious fruit.

Many of the *Moreæ* and *Artocarpeæ* contain a milky juice, which in some of them is bland and of agreeable flavour, and is used as a substitute for milk. This is the case, for instance, with the juice of the *Cow-tree* (*Galactotendron utile*). The juice of some others, on the contrary, is highly acrid and poisonous, as that of the *Antiaris toxicaria*, the source of the

famous Javanese poison, called *Bohun-Upas*, or *Upas-Antiar*. The milky juice of many of the *Artocarpus* tribe supplies caoutchouc, and so equally does that of several species of *Ficus*, as *e.g. Ficus elastica, F. Radula, F. elliptica, F. prinoides.*

168. PIPERACEÆ, the *Pepper family*. The plants of this order are natives of the hottest quarters of the globe, more particularly of the East and West Indies, and of South America. The dried unripe fruit of the *Pepper-tree* (*Piper nigrum*) constitutes the *black;* the ripe fruit, deprived of its outer fleshy covering, by washing, the *white* pepper of the shops. The *betel* leaves, mentioned § 181, come from a plant of this family, the *Betel pepper* (*Piper belet*).

169. AMENTACEÆ, the *Catkin-bearing family*. The plants of this extensive order constitute, together with the *Coniferæ*, the principal bulk of our woods and forests; they supply us with fuel, and yield valuable timber. Among them we find the majestic *Oak* (*Quercus robur*), the symbol of Saxon vigour and firmness; the slender *Beech* (*Fagus sylvatica*), the *Birch* (*Betula*), the *Alder* (*Alnus glutinosa*), and the *Hazel* (*Corylus avvellana*). The seeds are either oleaginous, as in the beech and hazel; or amylaceous, as in the *Edible* or *Spanish chesnut* (*Castanea vesca*), and in the oak; the seeds of the latter, however, the acorns, contain also tannin, which renders them unfit for food.

The bark of these trees contains *tannin*, and a bitter principle, which abounds more particularly in the willow tribe, and is on that account called *Salicin.*

We have still to mention here the *Poplar* (*Populus*), with its varieties, the *Abele* (*Populus alba*), the *Aspen* (*Populus tremula*), &c.; and the *Wax myrtle, Bay myrtle*, or *Candleberry* (*Myrica cerifera*), the fruit of which yields a greenish-colored wax, which is used for candles.

Section B. Gymnospermæ. (Seeds naked).

170. CONIFERÆ, the *Cone-bearing family*. The plants of this family are strongly characterised, more particularly by the *punctated* appearance of the woody tissue, and by the usually narrow, rigid or acerose leaves. They furnish fuel and valuable timber, and yield various important products, such as turpentine, spirit of turpentine, pitch, tar, resin, &c. (Chemistry, § 144.)

The most familiarly known of the order are the *Red pine* (*Pinus abies*), the *Silver fir* (*Abies picea*), the *Larch* (*Pinus larix* or *larix Europæa*), the *Scotch fir* (*Pinus sylvestris*). The seeds of the *Cluster pine* (*Pinaster pinus*), and of the *Sweet pine* (*Pinus pinea*), taste like almonds, with a slight flavor of turpentine. The *Cedar* (*Cedrus*), the *Cypress* (*Cupressus*), the *Yew* (*Taxus*), and the *Juniper* (*Juniperus*), belong also to this order.

CLASS II. MONOCOTYLEDONES.

The plants belonging to this great class have a *cellular* and *vascular* system, the latter consisting partly of elastic spiral vessels. The leaves are *parallel-veined*, except in the first subclass (*Dictyogenæ*), where there is an approach to reticulation; the embryo has one cotyledon.

Subclass I. DICTYOGENÆ. (Net-producing.)

171. DIOSCOREACEÆ, the *Yam tribe.* The various species of *dioscorea* produce the tubers called *yams*, which serve in warm countries as a substitute for the potato.

Subclass II. PETALOIDEÆ.

A. *Perianth adherent, ovary inferior, flowers usually hermaphrodite.*

172. ORCHIDEACEÆ, the *Orchis family.* The tuberous roots of some species of orchis yield a nutritious substance called *Salep*, which, boiled with water or milk, forms an excellent article of food for invalids. The beautiful flowers of *Orchis mascula, O. militaris*, and others, adorn our meadows. The beautiful *Lady's-slipper* (*Cipripedium*) is more rarely seen. To this order belongs also the *Vanilla plant*, (comprising *Vanilla planifolia, claviculata*, and other species), a native of Mexico, and the fleshy pod-like fruit of which constitutes that most delicious of all aromas, *vanilla.* The parasitic orchids of the warm regions of America are among the most charming and most curious ornaments of our conservatories, from the singular forms of their flowers, and the beauty of their colors.

173. ZINGIBERACEÆ, or SCITAMINEÆ, the *Ginger family.* Natives of warm regions, with aromatic stimulant properties residing chiefly in their roots and seeds. Ex., *Ginger* (*Zingiber officinalis* or *Amomum Zingiber*), a native of the East and West Indies: *Curcuma longa*, a native of Eastern Asia—this plant furnishes the turmeric of commerce; *Amomum cardamomum*, and other species of *Amomum, Elettaria*, and *Renealmia*, furnish the various sorts of cardamoms of the shops.

174. MARANTACEÆ or CANNACEÆ, the *Arrow-root family.* The tuberous rhizomata of *Maranta arundinacea* and *M. indica* supply the well-known arrow-root of commerce.

175. MUSACEÆ, the *Banana family.* There is not unfrequently seen in hot-houses a palm-like plant with gigantic leaves: this is the *Pisang banana* or *Plantain-tree* (*Musa paradisaica*), a plant of the greatest value to the inhabitants of the torrid regions of Asia and America, where its fruit, the plantain or banana, serves the same end as the various kinds of grain, the potato, the date-palm, &c. do in other countries. The same extent of ground which, planted with wheat, would feed two persons, will, planted with the pisang, supply food sufficient for fifty people. The gigantic leaves, which attain a length of from eight to ten feet, are also turned to various uses. The young shoots of the banana furnish a culinary vegetable. The woody tissue of many species of musa is turned to manufacturing uses in warm climates, as, *e. g.* the fibre of *Musa textilis*, which is made into fine muslins in India. *Urania speciosa*, or *Ravenala*, is the water-tree of the Dutch, so called on account of the great quantity of water which flows from its stem or leaf-stalk when cut across.

176. IRIDACEÆ, the *Iris family.* The yellow and the blue flag (*Iris pseudacorus* and *I. germanica*), and the *dwarf-flag* (*Iris pumila*), are among the fairest flowers of our gardens; these plants have bulbous roots. The root-stock of *Iris florentina*, a native of southern Europe, and more especially

of Tuscany, yields the well-known *orris-root*, which has the agreeable smell of the violet, and is used in perfumery and tooth-powders, and also to impart a pleasant odor to the breath. The stigmata of the *Saffron-plant* (*Crocus sativus*) constitute the coloring matter called *saffron*, which is also used medicinally.

177. AMARYLLIDACEÆ, the *Amaryllis family*. This order comprises many of our ornamental garden plants, as, *e.g.* the *Daffodil* (*Narcissus pseudo-narcissus*), the *Jonquil* (*Narcissus Jonquilla*), the *Narcissus poetica*, &c. The *Snow-drop* (*Galanthus*), the *Snow-flake* (*Leucojum*), the splendid exotic *Amaryllis*, and the *American aloe* (*Agave Americana*), belong also to this order. The latter plant attains a great age—some say a hundred years—before it puts forth flowers; but the inflorescence proceeds then with great rapidity and vigor, a flower-stalk being produced from twenty to thirty feet high, and covered with thousands of blossoms: after this inflorescence the plant dies.

178. BROMELIACEÆ, the *Pine-apple family*. The *Pine-apple plant* (*Ananassa sativa* or *Bromelia ananas*), the pine of our hot-houses, is a native of South America. The fruit, the well-known pine-apple or ananas, which is more or less acid in the wild state, has been brought to a high state of perfection by cultivation. It is highly aromatic, and has a delicious rich strawberry flavor.

B. *Perianth free, ovary superior, flower usually hermaphrodite.*

179. LILIACEÆ, the *Lily family*. Most of the plants of this extensive order have bulbs or tubers. The plants of the *Onion tribe*, which belongs to it, abound in mucilage, and contain a sulphuretted hydrogen oil of penetrating odor, and possessed of stimulating and irritant properties. The bulb of *Allium sativum*, garlic, is used as an irritant, stimulant, and diuretic, and also as a culinary condiment. The *onion* (*Allium cepa*), the *Leek* (*Allium porrum*), the *Shallot* (*Allium ascalonicum*), the *Chive* (*Allium schœnoprasum*), the *Rocambole* (*Allium scorodoprasum*), are used both medicinally and as articles of diet. Among the plants of this order that are prized for their showy flowers may be mentioned: the *Star of Bethlehem* (*Ornithogalum*); the *Cluster-flowered* or *Grape hyacinth* (*Muscari*); the common cultivated *Hyacinth* (*Hyacinthus orientalis*), originally imported from the East; the *Tulip* (*Tulipa*); the magnificent *White lily* (*Lilium candidum*), originally brought from Palestine; the *Martagon lily*, or *Turban*, or *Turk's cap* (*Lilium martagon*); the stately but poisonous *Crown-imperial* (*Fritillaria imperialis*); the *Tuberose* (*Polyanthus tuberosus*); and many more. The charming *Lily of the Valley* (*Convallaria majalis*), belongs also to this order; and the *Asparagus* (*Asparagus officinalis*), which grows wild in sandy soils, and when well manured with nitrogenous matters, supplies one of the greatest luxuries of the table.

The *Scilla* or *Sqilla maritima* supplies the officinal *squill*, which is used medicinally as an *emetic*, *expectorant*, *diaphoretic*, and *diuretic*. The bitter drug *aloes*, which is used medicinally as a cathartic, is the inspissated juice of various species of *aloe* (*Aloe spicata*, *vulgaris*, *socotrina*, &c.). The *New Zealand flax* (*Phormium tenax*), supplies most tenacious fibres, which are used for net-work.

180. Melanthaceæ, the *Colchicum family.* The plants of this order have, in general, poisonous properties. The most important medicinal plants of the order are: the *Meadow saffron* or *Autumn crocus* (*Colchicum autumnale*), and the *White Hellebore* (*Veratrum album.*)

181. Palmæ, the *Palm tribe.* These gigantic monocotyledons attain sometimes a height of nearly two hundred feet. Their long, straight stems, adorned at the top with clusters of large and broad arching leaves, impart a singularly imposing aspect to the landscape of the tropical regions where they grow. Linnæus calls them the princes of the vegetable kingdom, and they are the symbol of peace. Their uses are various and extensive. In the countries in which they grow they supply food for the people, and materials for the construction of their habitations; the fibres serve for the making of ropes; the reticulum surrounding their leaves is sometimes made into brushes; many supply oil, wax, amylaceous matter, and sugar, which latter, when fermented, yields an intoxicating beverage. Among the most important of the order we may mention: the *date-palm* (*Phœnix dactylifera*); the *Coco-nut palm* (*Cocos nucifera*), one of the most useful of the family; the various species of *Sago-palms* (*Sagus lævis* or *inermis*, *S. farinifera*, *Cayota urens*, *Saguerus saccharifer*), which supply the sago of commerce. *Palm-wine* is procured from *Cayota urens*, and other palms. The terminal buds of the *Cabbage-palm* (*Euterpe montana*), are used as culinary vegetables; and so are also the terminal buds of the coco-nut palm. The palms of the coco-nut tribe yield a fatty substance, and the yellowish-red, violet-scented palm-oil. The palm-oil imported from the west coast of Africa is obtained by bruising the fruit of *Elais guineensis* and *melanococca.* The *betel-nut* is the product of the *Areca palm* (*Areca catechu*); it contains tannin, and forms an ingredient in the Eastern masticatory called *pan* or *betle*, and which seems to owe its stimulant properties to the leaves of the *Piper betle.* (See § 168.)

182. Alismaceæ, the *Water-plantain family.* A small family of plants growing in flowing or stagnant water, and consisting chiefly of the genus *Water-plantain* (*Alisma*), and the arrow head (*Sagittaria*), so called from its large arrow-shaped leaves.

C. *Flowers incomplete, often unisexual, without a proper perianth, or with a few verticillate scales.*

183. Araceæ, the *Arum family.* In the plants belonging to this family the flowers are usually arranged on a *spadix* (§ 67). The large cornet-shaped flower of the common *Cuckoo-pint*, or *Wake-robin* (*Arum maculatum*), disengages a perceptible amount of caloric. The *root-stock* of the Sweet-flag (*Acorus calamus*) has an acrid bitter taste, and an aromatic odor; it is used sometimes in medicine as a tonic and stimulant. The *Calla*, a native of Africa, is extensively cultivated in our hot-houses, on account of its large pure white flower. The *Great reed mace* (*Typha latifolia*), and the *Bur-reed* (Sparganium), with its prickly fruit, are found in ditches and ponds, and by the sides of rivers, lakes, and brooks. The broad leaves of the Great reed mace are used by coopers to caulk the interstices between the staves of casks.

Subclass III. Glumaceæ.

184. Cyperaceæ, the *Sedge family.* To this family belong the *Carices*,

characterised by their solid, non-jointed, angular, creeping stem, and which often serve to bind together the loose sand on the sea-shore; they are not fit food for cattle, and will generally disappear when the land is properly drained and manured with ashes. The various kinds of *rush* (*Scirpus*), which are used chiefly for making chair bottoms, and the *Cotton-grass* (*Eriophorum*), belong also to this family.

185. GRAMINEÆ, the *Grass family.* One of the most extensive, and at the same time, most important orders in the vegetable kingdom; one great section of it supplying herbage for animals, another food for man. Among the former may be mentioned:—*Hair-grass* (*Aira flexuosa*); *Meadow-grass* (*Poa pratensis*); *Fescue-grass* (*Festuca pratensis*); *Timothy-grass* (*Phleum pratense*); *Meadow fox-tail* (*Alopecurus pratensis*); *Sweet vernal grass* (*Anthoxanthum odoratum*); *Rye-grass* (*Lolium perenne*); *Heath-grass* (*Melica*); *Brome-grass* (*Bromus racemosus* and *B. mollis*); *Bent-grass* (*Agrostis*); *Cock's-foot grass* (*Dactylis glomerata*); and the elegant *totter-grass*, or *quaking-grass* (*Briza media.*)

All the pasture grasses are Silica and Potassa plants (§ 98), and require manuring with Potassa (Ashes) and an abundant supply of water to effect the solution of the Silica in the soil.

In another section of the grasses the seeds abound in amylaceous matter, fibrine, and phosphate of lime, and are therefore singularly adapted to afford sustenance to man. The plants of this section are comprised under the general name of *corn*, *cereal grasses*, or *cereals*. Culture has not only perfected their seeds or grains, but has created also a number of varieties. Agriculture is coeval with the history of our globe. To this division belong *Wheat* (*Triticum*); *Rye* (*Secale*); *Oats* (*Avena*): *Barley* (*Hordeum*); *Rice* (*Oryza*), which thrives best in marshy regions, and constitutes the principal article of food in India and China; *Maize* (*Zea*), grown principally in America; *Guinea-corn* and *Millet* (*Sorghum* and *Panicum.*)

The following also belong to the extensive order of grasses:—*Phalaris canariensis*, which supplies the common canary seed; *Darnel-grass* (*Lolium temulentum*), which possesses poisonous narcotic properties; *Reed* (*Arundo Phragmitis*); *Spanish Reed* (*Arundo donax*), which is extensively used for wicker-work; *Bamboo* (*Bambusa arundinacea*), a large articulated reed, which grows as thick as a man's arm, and is, from its strength and lightness, suitable for building. But one of the most valuable grasses is the *sugar-cane* (Saccharum officinarum and its varieties), a native of the East Indies, but now widely spread over various parts of the world, and which supplies us with sugar, treacle, and rum. The work in the sugar plantations, in the marshy tracts of the tropical regions, is of the most severe description, and most injurious and destructive to the health of those engaged in it.

SECTION II. CRYPTOGAMOUS PLANTS. (Organs of reproduction inconspicuous.)

ACOTYLEDONS.

186. We have already designated the acotyledons as plants having no conspicuous flower, and accordingly no actual fruit or seed. Their propagation is effected by means of extremely minute germinating bodies, called

spores. The individual spores are often impalpably minute, and are thus readily wafted about and diffused wherever the air has free access; we need not marvel, therefore, to see plants of this class spring up, as it were, spontaneously.

The *spores* are aggregated together in so-called sori, *i.e.* clusters of *thecæ* or spore cases, on the under surface of the fronds or leaves, as in the *ferns;* or they are enclosed in cases, mostly provided with an operculum or lid, as in the *Mosses.*

In the more perfectly developed acotyledons, in the *ferns* for instance, organs have recently been detected, corresponding to the stamens and pistil of perfect (*phanerogamous*) plants. A most remarkable fact is that the spores of these plants present on their surface filaments, or vibratile *cilia*, by means of which they move about in fluids, like some of the infusoria.

Subclass I. ACROGENÆ (Summit producing), or CORMOGENÆ. (Stalk producing.)

187. Acotyledons having usually distinct stems and leaves, stomata, a certain amount of vascular tissue, and thecæ, or cases containing spores.

188. EQUISETACEÆ, the *Horse-tail family.* These plants, which are common on sandy fields, in woods, and marshy tracts, abound in silica, which impart to them the properties of a file, and adapt them for use in polishing mahogany and other woods. (See § 86.) When burnt with proper caution they leave a perfect skeleton of white silica.

189. FILICES, the *Fern family.* A rather extensive order of plants, which in external appearance considerably approach the perfect (*phanerogamous*) plants. The most conspicuous part of these plants are the *leaves* or *fronds*, which have a circinate (gyrate) variation, and are beautifully incised at the margin; on the under surface they bear clusters of *thecæ*, which are called *sori.*

In our forests we frequently meet with the *Eagle-fern* (*Pteris aquilina*); the *Male-shield-fern* (*Aspidium filix mas*, or *Lastrea filix mas*), which is used as a vermifuge, more particularly against the tape-worm. The beautiful *Lady's hair* (*Adiantum Capillus Veneris*), and *Maiden hair* (*Asplenium*), grow on rocks, and old brick-walls, &c.

The tree-ferns of the South Sea Islands, attain a height of from fifty to sixty feet. That the flora of former ages was rich in gigantic ferns, has been mentioned already in the mineralogical part. (See § 114.)

190. LYCOPODIACEÆ, the *Club-moss family.* Moss-like plants intermediate between *ferns* and *mosses;* they abound in warm, moist, insular climates. The thecæ contain a light yellow, very minute, and highly inflammable powder, which has been used as a substitute for sulphur, under the name of *Lycopode*, or *vegetable brimstone.* It is used also to cover pills to protect them from moisture.

191. MUSCI, the *Moss family.* Pretty little plants, erect or creeping, terrestrial or aquatic, found in all moist countries, from the arctic to the antarctic regions. They are useful in various ways, but principally in the dry state, when they afford material for stuffing mattresses, pillows, cushions, &c. One of the most remarkable of them is the *Turf moss*

(*Sphagnum*), the principal ingredient in the turf beds. (See Chemistry, § 166).

Subclass II. THALLOGENÆ (Green leaf producing), or CELLULARES.

192. Acotyledons, composed entirely of cellular tissue, having no distinct axis, nor leaves, nor stomata; propagated by means of spores, which are often enclosed in *asci*.

193. LICHENES, the *Lichen family*. Plants forming a thallus, which is either foliaceous, crustaceous, or pulverulent; they are found in all quarters of the globe, adhering to stones, rocks, trees, &c.

Cetraria Islandica, commonly called *Iceland moss*, enjoys some reputation in pulmonary diseases. The *Cladonia rangiferina* decks the ground in the far distant North, where it affords food to the reindeer. The *Gyrophora* (*Tripe de roche*), the *Sticta pulmonaria*, and many other species of Lichens, furnish articles of food. From the *Lecanora*, which grows in Sweden, the *Litmus color* is produced; from the *Lecanora tartarea*, the *Cudbear dye;* and from the *Roccella tinctoria* of the Canaries, and the *Roccella fuciformis*, the *Orchil* or *Archil*.

194. FUNGI, the *Mushroom family*. To this extensive order belong the various moulds which settle on bread, cheese, preserves, fruits, books, &c.; viewed through the microscope, they present most varied and elegant forms. The larger fungi are called *Mushrooms;* they, but more especially the poisonous species of them, abound in thick shady woods, on wet ground; the edible species grow more in meadows, in dry pastures, and not in the shade; and also on trees, as *e.g.* the *Cyttaria Darwinii*, a globular fungus of a bright yellow color, found on the bark of the beech in Terra del Fuego, where it forms a staple article of food. The rapid growth of mushrooms has become proverbial. Of the thousands of genera and species belonging to this extensive order we mention here only a few, such as the *Agarics*, with their delicate lamellæ or gills radiating from the centre, on the under surface of the pileus, and of which the best known edible varieties are—the *Common mushroom* (*Agaricus campestris*), *Agaricus Georgii*, *Morchella esculenta*, and other species of *Morel; Truffle* (*Tuber cibarium*); *Agaricus prunulus*, said to be the finest. Numerous species of fungi are poisonous, as *e.g.* the beautiful scarlet-colored, white spotted *Fly mushroom* (*Agaricus amanita* or *Amanita muscaria*). It is not easy to distinguish between edible and poisonous fungi. It is a remarkable fact that the poisonous fungi of warmer regions lose their poisonous properties in colder climates. The forests of the Ukraine are covered with fungi, which are eaten indiscriminately, and constitute, in fact, a staple article of food.

The *Sporous fungi* (*Boletus*), have, on the lower side, numerous perforations or pores; some of them are edible, others poisonous. The *Polyporus fomentarius*, which grows mostly on trees, form *amadou* or *German tinder*, and is occasionally made into razor straps, as is also the *Polyporus betulinus*. The white and intensely bitter fungus of the larch is employed as a cattle medicine. Many fungi which are generated in moist wood become highly dangerous to buildings, &c. from the rapidity with which they spread and carry destruction through the entire mass of the wood. An application of dilute sulphuric acid to the diseased wood will, in many cases, stay the

farther progress of this destructive plague. (Chemistry, § 106). Steeping the wood in a solution of corrosive sublimate is considered an efficient preservative against the attacks of fungus; this process is called *kyanizing* the wood. A more recently discovered process is the injection of certain antiseptic substances into the porous parts of the wood.

195. ALGÆ, the *Sea-weed family*. Cellular plants, widely distributed over the globe, found in fresh water and salt water, on damp rocks and stones, and even in hot springs. Some of them, of microscopic size, consist only of one single cell. Sometimes they present collectively the appearance of green slime. In many of them the cellular integument abounds in silica to an extent to impart quasi-crystalline appearance and stiffness to them. These constitute a separate subdivision — the *Diatomaceæ;* they abound in our stagnant waters and pools; we not rarely find fresh water deposits of their silicious skeletons, dating from former periods of the earth's history. The numberless dead bodies of *Diatomaceæ* are now producing, in the South Arctic Ocean, a submarine deposit, consisting entirely of the silicious particles which entered into the composition of these plants.

The *Water flannel* (*Conferva crispa*), forms beds of entangled filaments on the surface of water.

However, the more important *Algæ* are the numerous marine plants known under the name of *Tangle* (*Fucus*), and of which the ashes (Kelp and Barilla) abound in Iodide of Sodium, and are accordingly used for the production of Iodine. (Chemistry, § 38.) The *gigantic fuci* of the South Seas are reported by navigators to be from 500 to 1,500 feet in length, and to afford food and shelter to many thousands of marine animals.

The *Carragheen* or *Irish moss* (*Sphærococcus* or *Chondrus crispus*), supplies a nutritious article of diet, and is given also in pulmonary diseases, on account of the mucilage which it contains. The *Corsican moss* (*Plocaria* or *Gigartina helminthocorton*), were formerly used as a vermifuge.

ZOOLOGY.

1. ZOOLOGY is that branch of natural history which treats of animals, that is, of those organised living beings that, besides the faculties of nutrition and reproduction which they share in common with the plants, are endowed also with sensation and voluntary motion. In brief terms it may be defined as "*a knowledge of animals.*"

The animal body, like that of the plant, consists of a number of dissimilar parts, which have each assigned to them some function more or less indispensable for the accomplishment of the ends and purposes of the whole. As we have already stated in Botany, these parts are called *organs.*

The faculty of *voluntary motion* enables the animal to change its position relatively to surrounding objects, and also the position of its own component parts, and this not, as is the case with certain plants, such as the sensitive plant (*mimosa pudica*), for instance, under the influence of accidental external agencies, but from an independent impulse given from within. This impulse is designated as the *will* of the animal, and the acts and motions incited thereby are accordingly termed *voluntary* or *spontaneous.*

2. The *sensitive faculty* is another of the distinguishing characteristics of animals. Every animal seeks instinctively the most favorable conditions for the accomplishment of the ends and purposes of its being, and not only keenly feels the disturbing influence of any hostile external agency, but opposes to it the most active and energetic resistance in its power—unlike the plant, which submits with patient endurance to any and every treatment it may receive by the elements, on the part of the animal world, or at the hands of man.

The *perceptive*, and indeed, we may venture to add, the *reflective* faculty also, is susceptible of no mean development in animals. It is a familiar fact, that domestic animals will come to understand the modulations of the voice of their master, nay, even his very looks and gestures, and will regulate their conduct accordingly.

3. The relative perfection of an animal is in proportion to the number of its component organs, and to the variety and complexity of their structure. At the bottom of the scale we have animals consisting of one single organ, and approaching as closely as can be the simple vegetable cell. At the top, we have animals consisting of a great number and variety of marvellously complex organs.

Hence, a proper knowledge of the body of an animal can be attained only through the study of the organs composing it. Now, as man is the most perfect of animals, the contemplation and study of the organs composing the *human body*, must, of course, necessarily lead also to the knowledge of all the organs that occur in the *bodies of the animals* of all classes; and the comparison of the body of any given animal with that of man, will thus enable us to judge of the degree of perfection belonging to the former.

Besides, our own body is under our continual observation, and not alone are we familiar from infancy with its form and shape, but we can more readily form clear notions respecting many of the inner functions, than we could possibly derive from the contemplation of other animal bodies. Therefore, in commencing with the human body, and comparing this afterwards with the bodies of the various animals, we shall truly follow the natural way of investigation, viz., to proceed from the known to the unknown.

4. We divide the domain of Zoology into two principal sections. The first section treats of the organs and their functions; the second of the description, classification, and denominations of animals.

I. THE ORGANS AND THEIR FUNCTIONS.

ANATOMY AND PHYSIOLOGY.

5. The most superficial view of the human body suffices to show the diversity of its several component parts in *form* and *substance*, in *situation*, and in *functional purposes*. In reference to form and substance, what we perceive first is, that the human body consists partly of *fluid*, partly of *solid* matter. The fluid constituents of the body are either absorbed by the solid parts, or are enclosed by them, and have different denominations applied to them, according to their respective nature and condition. To the solid parts of the animal body we apply the general term "*tissue*," though it must be admitted that hardly any of the so-called tissues bear the remotest resemblance to what is otherwise generally understood by the term *tissue*.

6. Microscopic examination shows that the divers organs of the plant are all of them simply modifications of the cell; but the case is very different with the organs of the animal: in the latter we observe at least *four* distinct primary tissues, occurring either separately or in combination, and presenting no transition from one to the other, such as we see in the plant—for instance, in the merging of the *cellular* into the *vascular* tissue. (See Botany, § 14.) This greater diversity of the primary tissues is in itself a proof of the higher organisation of the animal body, as compared to that of the plant.

The four primary tissues of the animal organism are, the *cellular tissue*, the *muscular fibre*, the *nervous fibre*, and the *osseous tissue*.

7. Thus, a part of the animal tissues consists of *cells*, that is, of perfectly closed microscopic vesicles, with different contents. The walls of the cells in the epidermis, and the fine coats of mucous membranes, are formed of a horny substance. The fat consists of an aggregation of minute vesicles formed of albuminous matter, and filled with adipose substance. Cells containing colored granules, form the *pigmentary* matter which imparts the different colors to the skins of animals.

Cells are also lodged in the mass of other tissues, as *e.g.* in the cartilaginous substance of many bones, &c.

Another series of tissues consists of very fine cylindrical filaments or fibres, which, interlacing, form most of the mucous membranes, the capsular ligaments of the joints, &c.

8. The *muscles* of animals consist of flat fibres of two different kinds; one set being marked by transverse lines, or striæ, upon the surface; the other by globular or oval bodies, called *nuclei.* The former set of fibres are found in the red muscles of the trunk and extremities, in the heart, &c.; the latter in the alimentary canal, &c.

9. The *nerves* and the white substance constituting the brain and the spinal chord, consist of another kind of fibre, formed by a homogeneous pellucid coat, which encloses an oily matter. In the gray mass of the nervous system we find cellular bodies of a peculiar kind, the so-called *ganglia.*

10. The *bones* of animals consist of a laminate mass, in which the spindle-shaped osseous corpuscles are imbedded. The osseous mass is traversed in every direction by a complete net-work of minute channels filled with marrow. The *outer coat* or *enamel* of the teeth presents the same structure as the other bones, but is formed of peculiar and most intimately interlaced prismatic fibres. The *inner dense substance* of the tooth consists of a uniform nearly fibrous mass, traversed by a system of microscopic tubes or channels, the so-called dental channels.

11. We speak of the *relative position* of the different parts of the body only in so far as the division of the corporeal mass into several great sections, both externally and internally, is concerned.

The great outer mass of the body is called the *trunk;* and from this proceed four branches, called the *extremities* or *limbs.* The *head* forms another distinct part of the body; in man it occupies the *highest*, in the animals the *foremost* position. In the other classes of animals we find the utmost variety as regards the number of extremities; in some there are a multitude of limbs, others lack them altogether.

The upper part of the trunk is called the *thorax* or *chest;* the lower, *abdomen* or *belly.* If we open the trunk, we find that the interior presents a cavity completely filled up with certain organs, which we designate as the *viscera.*

The cavity of the trunk is separated by a strong membrane called the *diaphragm* or *midriff*, into the *thoracic cavity*, or *cavity of the chest*, and the *abdominal cavity.* In the former are placed the *lungs*, with the *trachea*, and the *heart*, with the *principal arteries.* The abdominal cavity, which is the

larger of the two, contains the *stomach*, the *intestines*, the *liver*, the *spleen*, the *kidneys*, and the *bladder*.

12. The classification of the organs is based entirely upon their respective *functional purposes*, and is altogether independent of their form, substance, structure, or position. We divide, accordingly, the organs of the body into —1. *Organs of motion;* 2. *Organs of digestion* and *nutrition*, *circulation* and *respiration;* 3. *Organs of the senses.*

A number of organs of the same or of different kinds, co-operating in the performance of a common function, are called a *system;* it is in this sense that we speak of the osseous system, the digestive system, the circulatory system, the generative system.

1. ORGANS OF MOTION.

13. The *motory system* is constituted by three different sets of organs acting in combination with each other, viz.: 1. the *bones;* 2. the *muscles;* 3. the *nerves.*

1. THE BONES.

14. The bones form the solid framework of the body, and the support of the muscular and tegumentary systems. They serve also to protect the most delicate and sensitive of our organs, forming a case for the brain and a tube for the spinal marrow.

The osseous framework of the animal body is called also the *skeleton.* In the skeleton we have the ground lines of the structure of the animal, all other outer parts serving simply as drapery, as it were. The skeleton then is, on this account as well as its durability, the most important part to study if we wish to acquire a proper insight into the structure of the animal body, —just as, to use a familiar expression, the structure of a roof can be judged of only from an examination of the inner framework, and not from the outer covering of it.

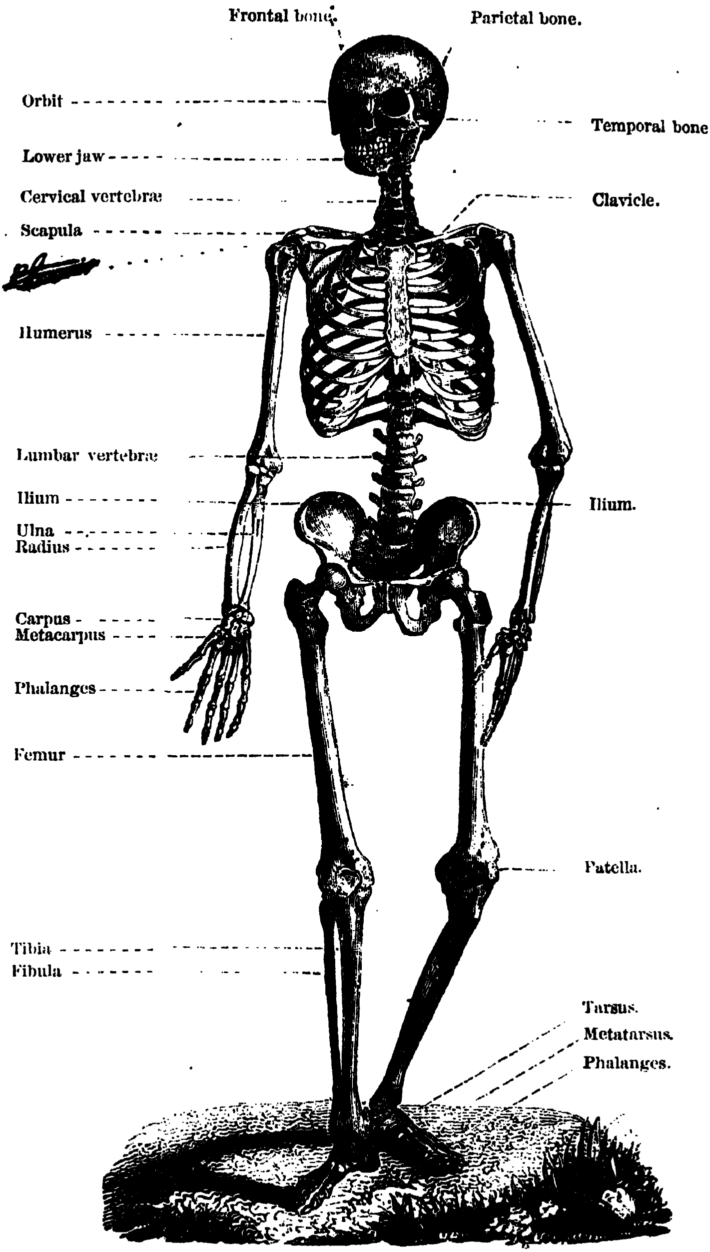
15. The bones consist of organic tissue, in which phosphate and carbonate of lime are deposited. (Chemistry, § 51.) 100 lbs. of fresh bones contain 33 lbs. of animal tissue, which may be extracted by boiling, in the form of glue or gelatine; the remainder of the weight is made up of 58 lbs. of phosphate of lime and 9 lbs. of carbonate of lime. The gristle of certain fishes, the ray, for instance, and the cartilage and cartilaginous parts of bones, contain less, and frequently only slight traces of lime, which makes them soft and flexible. Very hard osseous formations, such as the teeth, contain a larger proportion of lime than the other bones.

For the uses of bones as manure, and in the preparation of glue, bone-black, phosphorus, &c., see Chemistry, § 44 and § 51, and Botany, § 101.

The osseous framework is divided into bones of the *trunk*, the *extremities*, and the *head.* Fig. 1 represents the complete skeleton of the human body.

a. Bones of the Trunk.

16. The most important part of the trunk is the *vertebral column*, which is composed of a series of irregular small bones, called *vertebræ*, and amounting, in the human skeleton, to 33; viz.: 7 *cervical* vertebræ, or vertebræ of the neck; 12 *dorsal* vertebræ, or vertebræ of the back; 5 *lumbar* vertebræ,


Frontal bone.
Parietal bone.
Orbit
Temporal bone
Lower jaw
Cervical vertebræ
Clavicle.
Scapula
Humerus
Lumbar vertebræ
Ilium
Ilium.
Ulna
Radius
Carpus
Metacarpus
Phalanges
Femur
Patella.
Tibia
Fibula
Tarsus.
Metatarsus.
Phalanges.

1.

or vertebræ of the loins; 5 *sacral* vertebræ, which latter are united, forming the *sacrum;* and 4 *coccygeal* vertebræ.

The spine, or vertebral column, being thus composed of a series of separate bones, connected together by ligaments and muscles, possesses considerable flexibility. The bodies of the single vertebræ, and which occupy the anterior part (fig. 2, *a*), are flat; the posterior part is formed by the so-called *spinous process* (*b*). On both sides are the *transverse processes* (*c*), and in the centre there is a perforation through which the spinal chord passes. Thus, when these bones are fitted together, they form a continuous tube, in which that important nervous centre is lodged.

2.

Many animals have fewer vertebral bones than man; others have a greater number. Thus, in snakes we count 150, and even more vertebræ.

17. With the vertebral column are connected the *ribs*, which are attached in pairs to the bodies and transverse processes of the twelve dorsal vertebræ, so that there are twenty-four of them. The seven upper pairs are longer, and are called the *true*, or *pectoral*, or *thoracic* ribs; the five lower pairs are shorter, and are called the *short* or *abdominal* ribs. The ribs are united exteriorly to a long flat bone, called the *sternum*, or *breast-bone*, and which completes the framework of the *thorax* or *chest*.

b. Bones of the Extremities or Members.

18. The members are arranged in pairs; the two members constituting the pair are of exactly the same shape, and of equal development.

We divide the members into upper or anterior, and lower or posterior members.

Bones of the upper members.—The *scapula* or *blade-bone* is a large, flat, somewhat triangular-shaped bone, situated at the upper part of the back, and connected with the sternum or breast-bone by the *clavicle* or *collar-bone*.

The *blade-bone* forms at the point of connection with the *collar-bone* a round cavity, in which the head of the *humerus* or *upper arm-bone* is lodged. The *fore-arm* is formed of two bones, of which the *anterior*, situated in the direction of the thumb, is called the *radius;* the *posterior*, situated in the direction of the little finger, the *ulna*.

The hand is composed of three parts, viz. the *wrist* or *carpus*, the *hand* or *metacarpus*, and the *fingers* or *phalanges* (*phalanges digitorum*).

The *wrist* is formed of eight small cube-shaped bones, arranged in two lines. These small bones impart to the hand considerable ease and celerity of motion, and enable it to bear great and continued exertion. They more especially serve, also, to break the shock of sudden and violent collisions; thus, for instance, dropping on the hands will generally considerably lessen the severity of a fall.

The *hand* consists of five bones of about equal length.

The *thumb* has two, each of the four fingers three, bones, one for each joint.

The whole number of bones in the upper extremities is accordingly 64.

19. *Bones of the lower extremities.*—These bear in number, shape, and position, great analogy to those of the upper extremities. The *pelvis*, a

large, somewhat bowl or basin-shaped bone, which is posteriorly united with the sacrum, constitutes the uppermost portion of the lower members.

The *pelvis* consists originally of three distinct bones, which afterwards unite, viz. the *hip-bone, or os ilii*; the *sitting-bone* or *os ischii*; and the *share-bone*, or *os pubis*.

At the point where these three bones unite, they form a deep cavity or socket, in which the head of the *thigh-bone* or *femur* is lodged. The thigh-bone is the largest bone in the human body. At the lower end of it is placed in front a small, flat, triangular bone, called the *knee cap* or *patella*; the *tibia* or *shin-bone*, to which is attached the *fibula*, is articulated to the lower end of the femur.

The *foot* is, like the hand, composed of three parts, viz., the *tarsus*, the *metatarsus*, and the *toes* (*phalanges digitorum pedis*).

The *tarsus* is formed of seven bones, of which one, called the *astragalus*, is articulated to the lower end of the tibia; behind and beneath this is situated the *heel-bone* (*os calcis*), and in front of this the *navicular* bone, and the other four tarsal bones in a row.

The *metatarsal* bones, and the bones of the toes, correspond in number and position to the bones of the hand and fingers.

The whole number of bones in the lower extremities is accordingly 61.

c. Bones of the Head.

20. The bones of the head are more numerous in the child than in the adult, as some of them, which were originally separate, unite in the course of time; the joinings or *sutures* remain, however, always distinctly visible.

In the animal subject the head may generally be divided into a posterior and anterior part, the former consisting of the *skull* or *cranium*, the latter of the *jaw-bones* or *maxillæ*. In the human subject we designate the *cranium* as the upper, the *maxillæ* as the *lower* part.

21. The *skull* or *cranium* is formed anteriorly by the *frontal-bone*, posteriorly by the *occiput*, laterally and at the top, by the *temporal* and *parietal bones*, all of which are united by sutures. The *occiput* has a protuberance, and in many animals, a crest, near the top part; and at the lower part an aperture (the *foramen magnum*), which affords a passage to the so-called *medulla oblongata*, the connecting link between the brain and the spinal chord. Other bones, forming inner parts of the head, and united with those already mentioned, are the *nape-bone*, or *os sphenoides*, with its wings or *alæ*, and the *sieve-bone*, or *os ethmoides*; whilst the *vomer*, the *nasal*-bones, and the *lachrymal*-bones form the foundation or root of the nose.

22. The *maxillæ* or *jaw-bones* form in man the *lower*, in other animals the *anterior* part of the head; they are divided into the *upper-jaw* (*maxilla superior*), and the *lower jaw* (*maxilla inferior*). The upper jaw is formed by the two superior maxillary bones—(each of which may be said again to consist of several parts united into one)—united in the centre by suture, and having on each side two incisor teeth, one canine tooth, and five molar teeth.

The *lower jaw* in the human subject is formed of one piece, articulated on both sides, to the temporal-bone. In birds, fishes, and reptiles, the jaws are composed of several pieces, which are simply stuck together, as it were. In insects the *maxillæ* are quite separate, and act in the way of pincers.

23. The *teeth* are lodged in the jaws in cavities or sockets, called *alveolæ*. We number in the human skull 32 teeth, 16 in the upper and 16 in the lower jaw. They are divided into four sorts, viz., *incisors*, four in each jaw, and placed in front of the mouth; *canine teeth*, two in each jaw, and placed on both sides of the row of incisors; *spurious molars*, or *small grinders*, four in each jaw, following two and two after the *canine teeth*; and *true molars*, or *large grinders*, six in each jaw, and following three and three after the small grinders.

The upper and free portion of the tooth is called the *crown;* the lower portions are called respectively the *neck* and the *root*. The front teeth have a single root; the back teeth, a root with two, three, and occasionally four fangs.

The substance of the teeth is harder than that of the other bones; the outer coat, which is also the hardest part, is called *enamel*. In many animals, and more particularly in the herbivorous class, the enamel forms only a thin layer over the softer substance of the tooth, and is pretty rapidly worn off.

The molars, in the orders *rodentia* and *pachydermata*, on the contrary, are very durable, composed as they are of alternate plates of enamel and ivory, or enamel, bone, and *crusta petrosa* arranged transversely to the jaw. The molars in some animals, as in the beaver, and in the order *ruminantia*, are also very durable, being furnished with layers of *cortical substance*, as well as with ivory and enamel; the crowns of the molars are flattened, and they present very much the aspect of a ribbon folded upon itself. At the lower end of the dental root there is a small opening, through which a blood vessel and a nerve pass, conveying the necessary nutriment to the tooth, and imparting sensation to it.

The perfect development of the dental apparatus in man is accomplished at a comparatively late period, some of the large molars making their appearance after the age of twenty, and sometimes even much later. The first teeth fall out between the sixth and tenth year, and are replaced by others; but the teeth of the second set, if lost, are never replaced.

Not all animals have the four sorts of teeth we find in man; many of them lack, more especially, the small grinders. The canine teeth are often enormously enlarged, in which condition they are called *fangs* or *tusks*. The teeth are among the most important characteristics in the higher orders of animals, as from their structure, condition, and size, positive inferences may be drawn as to the natural economy of the animal, its mode of life, its size and age.

24. The whole number of bones in the adult body is 207. In the infant it is greater, as many parts of the osseous system consist, at that period of life, of cartilages, which afterwards ossify, several of them uniting to form a single bone. The dry clean skeleton of an adult weighs from nine to twelve pounds, constituting thus from one-sixteenth to one-eleventh part of the whole weight of the body, taking this on an average at about 137 lbs.

25. It is only in the more perfectly developed classes of animals that we find bony or cartilaginous cases for the brain and the spinal marrow. The presence of the vertebral column affords, therefore, a characteristic mark of the higher classes of animals. This has led to the division of the whole animal kingdom into two great classes, viz., animals with a vertebral

column, and hence called *vertebrate* animals; and animals lacking that osseous or cartilaginous case for the nervous centre, and hence called *invertebrate* animals. To the former belong the *mammals* (*mammalia*), the *birds* (*aves*), the *reptiles* (*amphibia*), and the *fishes* (*pisces*); to the latter, the *crustaceous animals* (*crustaceæ*), the *insects* (*insecta*), the *worms* (*annelida, entozoa, rotifera*), the *acalephae*, the *zoophytes* or *polypes*, (*polypifera*), and the *infusoria*.

26. The bones are covered with a fine and mostly very sensitive membrane called the *periosteum*. The osseous substance is traversed by a number of very minute blood vessels, which convey the nutritive matter to the bone; but, with the exception of the teeth, the bones have very few nerves. The inner mass of the bones is usually less dense than the outer coats; it is often quite porous or spongy, or even presents a complete hollow, filled up usually with a fatty substance called *marrow*. The calcareous matter in the bones increases with age, a proportionate decrease taking place, of course, in the gelatinous substance; this tends to make the bones more brittle and liable to fracture than they are in youth and manhood. In birds nearly all the bones are hollow, and are therefore lighter, with an equal volume, than the bones in the mammals.

The bones are not in immediate contact with each other at the joints, but a soft cartilaginous substance intervenes between them. The condyles are coated over, and the sockets are lined with exceedingly smooth cartilage; and over and above this, the articulation is kept anointed with the *synovial fluid*, which effectually prevents all friction between the articular surfaces.

2. The Muscles.

27. The muscles consist of an aggregation of very fine contractile filaments or fibres. In 100 parts, by weight, of dried muscular fibre we find 54 parts of carbon, 7 of hydrogen, 21 of oxygen, 15 of *nitrogen*, and small portions of sulphur, phosphorus, and alkalies (1·4 per cent). The fresh muscle contains 77 per cent of water. In the mammals and birds the muscles are red, in the reptiles they present a pale hue, and in the fishes they are white. In the invertebrate animals the muscles are only imperfectly developed, but still they may be distinctly traced, even in the lowest orders of them. In common parlance the muscles of an animal are called the *flesh*.

28. The muscles completely invest the bones, with the exception of the teeth. As a general rule, muscles are thickened in the middle and attenuated at the ends; they are enclosed in a peculiar membrane or sheath, which separates them respectively from the contiguous muscles. The thin ends of the muscles are remarkably tough; they are called *sinews* or *tendons*, and are always attached to the bones. The muscles are covered either by a layer of fat, of greater or less depth, or immediately by the cuticular integuments. Numerous blood-vessels spread through their substance, to supply the requisite nutriment; the muscles receive also many motory nerves, but only few nerves of sensation, so that a muscle may be cut without much pain being inflicted thereby.

The connection between the muscles and the bones is always so arranged that every muscle is attached to two bones. Thus, for instance, the so-

called two-headed brachial muscle is with the upper end attached to the humerus, with the lower to the radius. When this muscle is contracted, the forearm is bent inwards. The various muscles differ considerably in length and power. Every muscle has some definite motion appointed to it; but there are many movements also which require the joint action of several muscles. Hence the dividing of a muscle may either altogether put an end to a motion, or it may simply weaken or modify it. The same muscle which changes the position of a limb, or any other part of the body, cannot restore it to its original position; the restoration to the original position is always effected by a second muscle, acting in an exactly opposite direction to the first. Hence we divide the muscles of the extremities into *flexors* and *extensors;* the former pass over the inner, the latter over the outer angle of the joint.

29. The number of pairs of muscles in the human body amounts to 238. The enumeration and description of them forms, under the name of myology, a special branch of the science of anatomy.

The expanded muscles, which, for instance, in the hedgehog, enable that animal to roll itself up into a compact round ball, and to make its sharp spines radiate all round, and stand out in every direction; in the horse, to move the integuments covering the back; in the human subject, to move the skin of the head, deserve a passing allusion here.

3. The Nerves.

30. The matter of which the nerves consist is essentially peculiar, both in form and composition. It presents the appearance of a white, caseous, *marrowy* substance, which in some parts is collected into larger masses, surrounded by a *gray* substance; whilst in others, it assumes the form of filaments or chords, which are mostly interlaced and reticulated.

Under the microscope, the nervous tissue appears as a mixture of gray and white matter—of fat and albumen. One hundred parts, by weight, of it contain 66 parts of carbon, 10 of hydrogen, 19 of oxygen, 2 of nitrogen, and 0·9 of phosphorus, which gives a larger proportion of the latter substance than is contained in any other of the animal tissues.

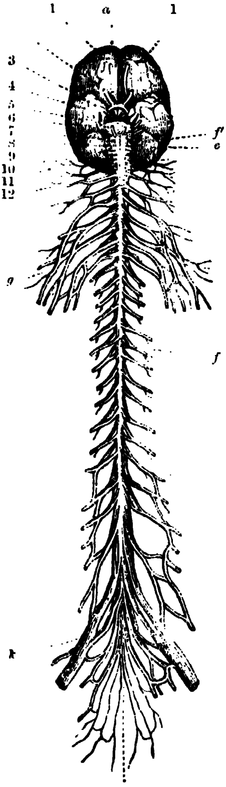
31. The largest mass of nervous tissue in the body constitutes the brain. This is enclosed and protected by the solid bones of the skull, and beneath them, more immediately, by the *dura mater*, or hard *brain membrane.* Its form is hemispherical, and its bulk corresponds to the size of the upper portion of the head. It is divided by a deep indentation into two halves. The surface of the brain is very uneven, from the irregularities of its folds or *convolutions*, producing numerous humps or eminences, by the aid of corresponding depressions. The portion of the brain occupying the fore and upper part of the skull is called the *brain proper* (*cerebrum*), and is separated by a deep fissure from the *little brain* (*cerebellum*), which is lodged in the posterior part of the cranial cavity. The brain is continued into the *medulla oblongata*, which passes through the *foramen magnum* in the occipital bone, and forms, as it were, the connecting link between the brain and the spinal chord. The weight of the human brain is about 2½ lbs., that of the entire mass of the nervous system about 3 lbs.

The nutrition of the cerebral substance is provided for by several arterial trunks, which spread their branches through it.

32. The *nerves* present the appearance of fine white filaments; they issue from the brain and spinal marrow, aggregated in bundles, and spread thence in every direction through the body, separating and diverging in proportion as they get farther away from their source. In this manner the nerves are diffused through every part of the body, endowed with sensation, or having some function to perform.

33. According to the different purposes which the nerves respectively subserve in the animal economy, we divide the nervous system into two branches, viz., the *animal* branch, and the *vegetative* branch; the former comprises the motory nerves, and the nerves of sensation; the latter branch is charged with the nutritive function.

a. Nerves of Sensation and Motory Nerves.



3.

34. We mention of course here only the principal trunks, which are represented in fig. 3, cut off a short distance from their source. They spring either from the brain (*a*), or from the medulla oblongata (*f'*), or from the spinal chord (*f*); the cerebellum (*e*) sends forth no nerves. The nerves, like the muscles, run always in pairs.

We count 12 pairs* of cerebral nerves, which are marked in fig. 3 by corresponding numbers. They are—1. The olfactory nerves. 2. The optic nerves. 3. The motory nerves of the eyes. 4. The pathetic nerves. 5. The trigeminal nerves, which separate into three branches, subdividing again into minor branches, and from which spring, among others, the lachrymal nerve, the nerves of the palate and of the teeth, and those of the tongue. 6. The abducent nerves of the eyes. 7. The facial nerves. 8. The auditory nerves.

The remaining four nerves, which spring from the medulla oblongata, are only partly distributed in the head, and send out branches to the other parts of the body, especially to the viscera, and more particularly to the stomach and to the intestines. This affords a key to many remarkable phenomena; it explains, for instance, the reason why the irritation produced by worms in the intestines, is felt also as a tickling sensation in the nose, and why headache is almost invariably a concomitant of derangement of the stomach.

The *spinal nerves* amount to thirty pairs, of which there are eight cervical, twelve dorsal, five lumbar, and five sacral nerves. The fifth to the eighth cervical, and first dorsal nerves form a plexus *g*, in which the nerves of the arm originate; the five lumbar nerves unite in the same way to form the great lumbar or femoral plexus *k*, which furnishes the nerves of the lower extremities.

* English anatomists generally make only nine pairs, comprising respectively in one pair, the seventh and eighth, the ninth and tenth, and the eleventh and twelfth.

b. Nerves of the Viscera.

Ganglionic System—Nervous System of Organic or Animal Life.

35. All the spinal nerves send branches to the anterior side of the vertebral column, which is turned to the viscera; these branches combine with each other, forming tubercles or *ganglia* and *plexus*, which receive besides several branches from some of the cerebral nerves. Thus there is constituted a double chain stretching along the front of the vertebral column, from the head down to the coccyx, and presenting, at certain distances, *ganglia*, from which nerves branch out at every part of the viscera.

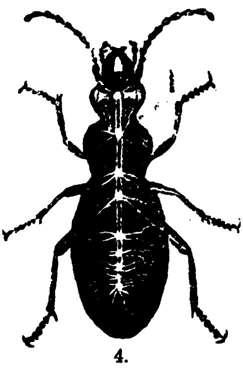
The most important among these ganglia or nervous centres are the upper and the lower cervical ganglion, and thoracic ganglion; the large and the small splanchnic nerves, with the solar plexus, and the renal plexus.

It is a distinguishing characteristic of the nerves of organic or animal life, that they do not run in chords alongside each other, branching off at certain distances, but issuing from ganglionic centres, as we have seen just now, and spreading in different directions, unite again in ganglia, and form there a kind of net-work.

This part of the nervous system is, therefore, usually termed the *ganglionic system.*

Another point to be observed is, that the nerves of the ganglionic system perform their functions quite independently of the will. The respiratory, digestive, and circulatory processes are going on in the organs respectively charged with these functions, even during sleep, and whilst we are perfectly unconscious of them. Neither do these nerves convey to the great centres the impression of external influences. Although the stomach, the intestines, and the blood-vessels are abundantly supplied with nerves, yet these latter do not intimate to us the arrival of the food in the stomach, nor its motion through the intestines, and leave us unconscious also of the circulatory motion of the blood in the vascular system. How different is the case with the nerves of sensation and the motory nerves, which not only perform their functions with lightning speed at the bidding of the will, but also convey instantaneously to our perception even the slightest external impressions.

36. In the mammiferous animals, the birds, the reptiles, and the fishes, the nervous system is pretty uniformly developed. In insects we find a series of ganglia arranged along the central line of the body, connected by a double chörd, and sending out on both sides lateral filaments. (See fig. 4.)



4.

In the mollusca also we find still a nervous system, though much less complex than in the articulated animals, and reduced in the lowest orders to a single ganglion. And even as the gelatinous polypi show vestiges of rudimentary nervous system, there is reason to assume that no animal is altogether destitute of nerves.

37. The chief mass of the nervous system constitutes the *brain*, which is the centre of all sensations, and justly considered as the seat of the in-

tellectual faculties. Every injury to this most important organ is attended with a corresponding disturbance of the intellectual functions. By simple mechanical pressure exerted upon the brain of the animal, it may, for the time being, be deprived altogether of all powers of motion; and a protracted continuance of the operation will even lead to the death of the animal. Pressure confined to one side of the brain produces partial paralysis. Lesions of the brain, therefore, are always dangerous; serious injuries to the medulla oblongata, from which so many of the nerves of the head spring, and upon which the respiratory function depends, cause instantaneous death. Even the most gigantic and powerful body is struck down instantaneously, as if by lightning, if the medulla oblongata is severed, where it issues from the skull, that is, in the nape of the neck, above the first cervical vertebra.

In ancient warfare, when the wounded elephant, maddened with pain, would sometimes turn against the ranks of his owners, his conductor had simply to drive a chisel into that part of the neck, to disable the huge animal in an instant.

Lesions of the spinal marrow are almost equally dangerous.

Internal perturbations of the nervous system also may imperil the life of the subject. Violent congestions of blood in the head will often suddenly suspend the action of the nerves, and cause what is usually called apoplexy. There are a number of substances which act injuriously upon the brain, some of them causing excessive cerebral excitement, followed by corresponding depression, others exercising direct paralysing action. To the former category belong alcohol, opium, strychnine, and the narcotic poisons in general; to the latter, more especially hydrocyanic acid. Giddiness, vertigo, frenzy, prostration, stupor, death, are the different degrees of the effect produced by these agents upon the great nervous centres.

38. The intimate connection existing between the mind and the nervous system is most clearly demonstrated by the influence which purely mental or moral impressions exercise upon that system. Severe mental exertions will often bring on headache. Sudden strong emotions, more particularly sudden joy, or sudden fright, may cause the same perturbations in the cerebral functions, as usually result from lesions of the brain. Loss of consciousness, stupor, madness, and even sudden death, are not unfrequently the consequence of violent mental emotion.

The contemplation of facts like these has naturally led to a belief that the development of the moral and intellectual faculties depends in a measure upon the size and development of the brain, and that the differences observable between the convolutions, protuberances, and depressions in the brains of different individuals, correspond to certain definite differences in their respective mental faculties and intellectual capacities; and inasmuch as the cranial bones are known to accommodate themselves to the protuberances and depressions of the brain, which they enclose, certain physiologists have thought that the bumps of the skull might serve as a guide to the correct divination of the moral dispositions and tendencies, and intellectual capacities of an individual. This theory, which certainly looks plausible enough, has, by the ingenuity of its authors and chief supporters, Gall, Spurzheim, and Combe, been raised to the rank of a quasi-science, known by the name of *Phrenology*.

Motion.

39. The various movements of the body are the result of a peculiar joint action of the nerves, muscles, and bones; the latter, however, co-operate only in so far as they afford the basis or support to which the muscles and tendons are attached. The movements are effected by the contraction of these muscular fibres, and the shortening of the muscles caused thereby. The contractile faculty is not inherent in the muscles, but is imparted to them by the action of the nerves, and the lesion or section of a motor nerve impairs or destroys the motor power of the muscle or muscles which it supplies. The nerves are accordingly the *true motor agents* in the human body, the muscles and bones being simply the *instruments* through which the motion is effected.

40. Careful and minute researches and experiments have shown that the different portions of the nervous system contribute very unequally to the phenomena of motion. The respective functional intention of the several component parts of the system is as follows:—

From the *brain* and *spinal marrow* proceed the nerves, which preside over sensation and voluntary motion. Some of these nerves, such as the third, fourth, sixth, seventh, and eleventh pairs of cerebral nerves, are exclusively *motor*, the others serve both the purposes of sensation and of motion. Strictly speaking, however, this is not precisely correct; the fact is, every bundle of nerves that proceeds from the spinal chord, consists of several distinct filaments, which do not unite on their way, but run on separately from their source to their destination; some of these filaments are appropriated exclusively to sensation, others exclusively to motion, and although it is difficult to distinguish them in the *bundles*, yet at the point of their origin their individual distinctness may be clearly made out upon close examination. All the nerves proceeding from the spinal chord originate in two distinct sets of roots, of which the posterior give birth to nerves of sensation, the anterior to nerves of motion, both of which run afterwards together in the same bundle; it has been shown experimentally that the section of the posterior roots deprive the body of sensation, the power of motion continuing; whilst the section of the anterior roots take away the latter faculty, leaving that of sensation unimpaired.

The *cerebellum*, and the parts of the brain contiguous to it, are intended to serve rather the purpose of regulating and directing the movements of the body, than of inciting them; the results of certain experimental section and lesions of these parts have shown that animals injured in this way lose the power of moving, except in one definite direction, as forward, backward, laterally, &c.

The *medulla oblongata* presides over those movements which, though going on *spontaneously*, remain still subject in some degree to the control of the will, as is the case with the respiratory function.

The *visceral nerves* (the *ganglionic system*) finally preside over the action of those muscles which are altogether independent of the will.

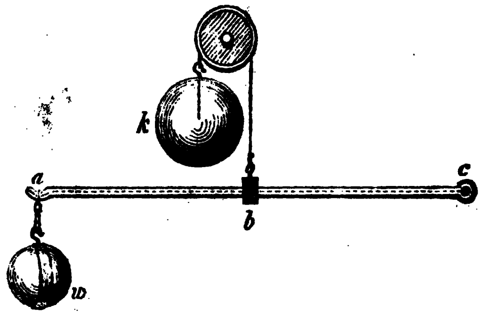
41. The manner in which the nerves determine the contraction of the muscular fibre remains still matter of speculation. *Galvani* made, in the year 1789, the discovery that the electric current will cause a similar con-

traction of the muscular fibre to that induced by the nerves. (Physics, § 191.) This naturally led to a notion that electricity was the real cause of all muscular movements. There are, however, many and weighty reasons that strongly militate against the correctness of this notion.

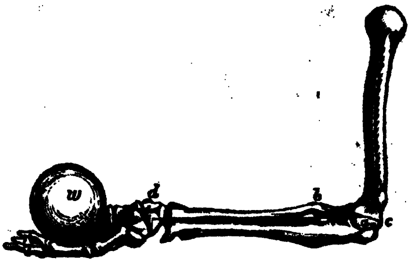
42. The contraction of the muscle is of limited duration; even the most powerful muscle gets sooner or later *wearied* and *exhausted*, and returns involuntarily to its relaxed condition. When it has remained for some time in a state of *relaxation* or *rest*, it reacquires the faculty of contraction.

The vigor or intensity of the contraction of a muscle depends upon the size of the latter, and upon the energy of the will brought to bear upon it. To what a degree the latter may heighten the muscular force, is shown by the remarkable instances of the enormous strength exhibited sometimes in danger, passion, and madness.

43. The usual motions of most of the limbs of the human frame may be compared to those of a single-armed lever, as represented by fig. 5, having its fulcrum at *c*, with a downward pressing weight (*w*), placed at the opposite extremity (*a*), and an upward pulling weight (*b*) attached to a point lying between the two ends, and which represents the elevating muscle.



The fore-arm in fig. 6 may be looked upon in the light of a lever of this kind, having its centre of motion in the elbow-joint (*a*), and at the other end the downward pressing weight (*w*), whilst the elevating muscle is attached at *b*. From the physical laws developed and elucidated in the physical part of the present work (§ 59), it follows that we are able to sustain the greater weight the nearer we place it to the fulcrum at *a;* thus we can support a heavy basket in the elbow joint, which we might be unable to hold out in one hand. Assuming the distance from the elbow-joint to the middle of the hand to be fifteen inches, the same weight which, placed at the distance of *one* inch from the fulcrum of the joints, would draw downward with a force of 2 pounds, will, when placed in the middle of the hand, draw downward with a force of 15 × 2 pounds = 30 pounds.



6.

II. VITAL ORGANS.

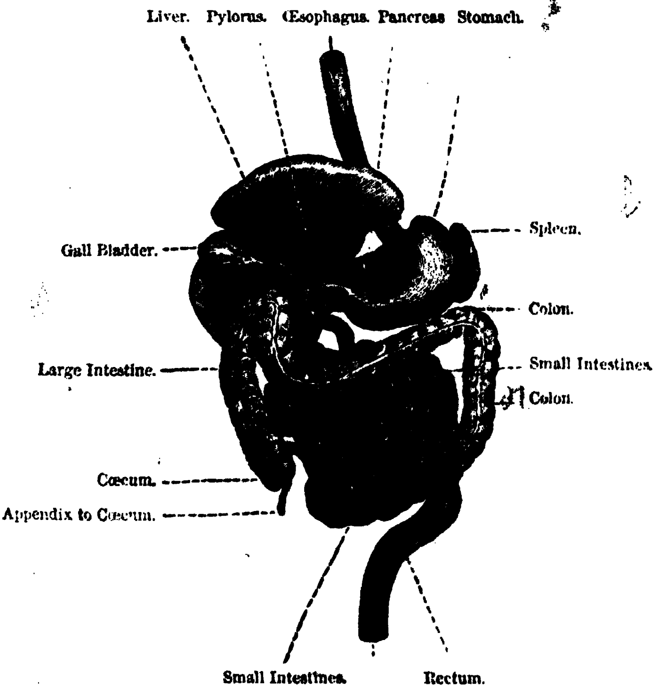
44. The vital organs are those of digestion, assimilation, nutrition, secretion, circulation of the blood, and respiration. In the lower animals, the respective digestive, circulatory, and respiratory apparatus are represented by simple organs. But in the higher orders of animals, several, and often very differently formed organs, co-operate in the performance of their respective functions (the digestive, the circulatory, and the respiratory); constituting their so-called systems of organs.

1. Organs of Digestion.

45. We apply the term *digestion* to the collective functions of a certain set of organs charged to convert the food ingested into the body into a proper state to subserve the purposes of nutrition,—in other terms, to *assimilate* it. All the organs co-operating directly in their assimilation of the food, are termed *digestive* organs.

The principal function of the true digestive organs consists more in the comminution (solution) of the food than in its transmutation or *elaboration*, which latter is a part rather of the *nutritive* function.

A collateral function of the digestive organs consists in the elimination and ejection from the body of those parts of the food ingested, which cannot be turned to account in the animal economy.



7.

46. The most simple form of the digestive organs is that of a cylindrical-shaped bag, open at both ends, and which is usually termed *alimentary canal*. The upper orifice, which receives the food, is called the *mouth*, the opposite opening, through which the useless parts of the food are ejected, is termed the *anus*. The enlargement of the alimentary canal between the two openings, is called the *stomach*. However, in the higher classes of animals, the digestive apparatus comprises, besides the alimentary canal, a set of collateral organs, as represented in fig. 7.

In this illustration the natural position of the organs is slightly altered, for instance, the anterior lobe of the liver is raised, as otherwise it would almost completely conceal the gall-bladder and the stomach.

47. The comminution of the food begins in the mouth, where the alimentary substances undergo the process of mastication. The masticatory apparatus is exceedingly powerful, the lower jaw forming an angular lever with upward action. The tongue moves the food about in the mouth, placing it in a convenient position for the teeth to lay hold of, to cut, and to crush it. Whilst the food is thus being chewed, it is mixed also with *saliva*, a fluid secreted by the *salivary* glands, of which there are three pairs, viz. the *sub-lingual*, under the tongue; the *parotid*, near the ear; and the *sub-maxillary*, situated inside the lower jaw.

The *saliva* is a colorless watery fluid, which holds in solution about 1 per cent of solid substance. Its object is to moisten the food, and thereby to facilitate deglutition. Although saliva can hardly be said to possess a greater solvent power than water, yet experiments have fully proved that food properly chewed and mixed with saliva is always more readily digested than food that has been swallowed in small lumps or bits, without having previously undergone the masticatory and salivatory process. Fresh saliva shows an alkaline reaction to vegetable color. (Chemistry, § 17.)

48. From the mouth the food passes through the *œsophagus*, which is called also the *gullet* or *throat*, into the *stomach*. This is a strong membranous bagpipe-shaped bag, which lies across the cavity of the abdomen, close under the *diaphragm*, and is covered anteriorly by the liver. On the left side, where the œsophagus enters, forming the *cardia* or *cardiac orifice*, or *mouth of the stomach*, the organ is enlarged. The opposite end, which is termed the *pylorus*, and leads into the bowels, is contracted to a narrow compass. Both the cardiac orifice and the pylorus are constricted and closed during the digestive process by an annular muscle. Behind the stomach, on the left side, lies the *spleen*, an organ apparently formed of the minute ramifications of an artery. Its functions remain as yet a matter of speculation.

The inner coat of the stomach is surrounded with a layer of muscular fibres, by means of which it may be compressed. This layer is in many animals, and more especially in domestic fowls, very strong, imparting to the stomach of such animals the power of crushing very hard substances. When the stomach is empty, its walls are contracted, and present at their internal surface a multitude of folds, which decrease in proportion as the organ becomes distended again upon the ingestion of food. The inner coat of the stomach is lined with a mucous membrane, which secretes an acid fluid, called the gastric juice.

49. The *gastric juice* contains 98 per cent of water, holding in solution a little chloride of sodium (common salt), and some hydrochloric acid. It was formerly supposed that the food was comminuted in the stomach by trituration between the hard coats of that organ; experiments have proved, however, that this is not the case. The real explanation of the process is, that the alimentary substances are dissolved by the gastric juice. Even the gastric juice taken out of the stomach of slaughtered animals will effect their solution, when brought into contact, at a proper temperature, with small chopped pieces of meat, &c. Nay, even artificial imitations of the gastric juice have been found to produce the same effect, though always most rapidly when mixed with a certain proportion of the natural fluid; which has naturally led to a notion that the gastric juice contains some peculiar, organic, digestive principle.

50. The action of the gastric juice accordingly reduces the alimentary matter into a thick pulpy mass, called *chyme* or *chymus*, which then passes through the pylorus into the *intestines*, and first into that part which is called the *duodenum*, on account of its being about 12 finger-breadths in length. The intestines, which in the human body reach altogether a length of about 30 feet, lie in the abdominal cavity, folded together in many convolutions. We distinguish in them several different portions, to which appropriate names have been given.

The digestive process continues in the duodenum, where the chyme is mixed with the *pancreatic juice*, a fluid secreted by the *pancreas or pancreatic gland* (see fig. 7), and which is very similar to the saliva, and with the *bile*, which is conducted from the *gall-bladder* into the duodenum, through the *biliary duct* (*ductus choledochus*). The bile is a clear, green, intensely bitter fluid; it feels soapy to the touch, and is in fact a natural soap, being a compound of fatty acid (Chemistry, § 137), with soda; like other soaps, it has a feebly alkaline reaction. It is often used in lieu of soap in the cleaning of delicate textile fabrics.

51. The *liver* is the organ in which the bile is secreted; it is the largest of the viscera. The hepatic substance or parenchyma of the liver consists of an agglomeration of small, solid, granular particles, and is pervaded by a multitude of blood-vessels; from those hepatic particles spring minute canals, which secrete the bile. The colour of the liver is dark reddish-brown.

52. The digestive process terminates with the admixture of the bile with the chyme; the latter consists now of two parts, the one solid the other fluid. The former (the solid part) is not adapted for assimilation, and is therefore ultimately ejected through the anus. The fluid portion, on the contrary, holds in solution all the available nutritive matter of the food; the fluid part is called *chyle*. The chyle is colorless; in every other respect it is nearly identical with the blood.

53. The contents of the duodenum pass gradually into the *small intestines*, which constitute a long, narrow canal, convoluted in many folds, so that the passage through them is an operation which requires some time. The intestinal contents are moved forward in the intestines by an incessant peculiar vermiform movement of the latter, which is called the *peristaltic* motion. The inner mucous coats of the small intestine presents numerous small prominences, consisting of a spongy cellular tissue, and called *villi*; these absorb

the chyle, and from them arise the chyliferous lymphatic vessels which conduct the chyle into the thoracic duct. The latter opens into the *subclavian vein*, when the chyle is ultimately admixed to the blood. The farther the contents of the intestines proceed in their downward course the more they lose of the nutritive elements of the food; and when they ultimately reach the widening part of the intestine, which is called the *large intestine* (*colon*, see fig. 7), they consist almost entirely of matter unavailable for the purposes of nutrition. The intestinal contents have now acquired greater consistency and solidity, incipient decomposition sets in, and the fecal matter is then ultimately ejected.

54. Not all articles of food are equally digestible. As a general rule, hard and compact substances are less easily digested than similar substances of less consistence. Matters that remain undigested after a certain time pass on along with the digested portion, and are thus ejected from the body without contributing to its nutrition. The presence of matter of this kind often causes pain and uneasy sensations.

Accurate investigations have shown, as indeed the common experience of every day teaches, that the chymification of readily digestible food takes from one hour to one hour and a-half. The following are most easily digested: asparagus, hops, spinach, celery; ripe fruit, preserved fruit; pap of cereal grains, such as rye, barley, rice, maize; peas, beans, chestnuts; bread one day old; light pastry; turnips, potatoes; veal, mutton, fowls; soft-boiled eggs, milk; fish boiled in water.

Among the less digestible substances, and which are only incompletely chymified within the given time, we may mention the following: salads, such as lettuce, water cresses, endive, white cabbage; onions, raw or boiled; horse-radish, carrots; dried fruits, figs; newly-baked bread, patties; pork, no matter whether roast or boiled, fresh or salted, or cured; boiled blood, cheese, hard-boiled eggs, omelettes, and pancakes.

The following matters are not digested within the given time, and must accordingly be looked upon as indigestible, or, at all events, very difficultly digestible: the edible mushrooms; all nuts and fruit kernels; the vegetable oils and fats; dried raisins; the skins of beans, peas, lentils, rye, barley; the husks of peas and beans; the skins of cherries, &c.; and the peel of apples, &c.; the membranous and gristly parts of every kind of flesh; cartilages and bones.

Warm aliments are more easily digested than cold, as the high temperature of the stomach greatly promotes digestion, and so the injestion of cold food must necessarily tend to reduce that temperature.

2. Organs of Circulation.

55. The organs in which the blood circulates are called *vessels* or *blood-vessels*. They consist of cylindrical tubes, connected with each other, and forming a complete system of channels, which convey the nutritious fluid from the heart to all parts of the body, and from the latter back again to the heart. This system is called the *vascular system*.

According to the different nature of their fluid contents, the vessels are divided into two classes, viz., the *arteries*, which convey a bright red fluid (arterial blood); and the *veins*, which convey a dark red fluid (venous blood).

Besides these two, the *lymphatic absorbent* or *chyliferous vessels*, which, as has been mentioned already, convey the colorless chyle, form also part of the vascular system.

56. The circulatory function serves a threefold purpose in the animal economy: 1. the nutritive principles supplied by the food are conveyed to all parts of the body; 2. the detritus of the several organs and parts is eliminated and removed; 3. a uniform temperature is diffused and maintained in every part of the body.

The Blood.

57. The average weight of a man of forty years of age is estimated at 137 lbs., of which two-ninths = 30·5 lbs., represent the weight of the blood. The blood is a non-transparent, intensely red fluid, of the following composition:—

Constituent parts of the blood.	100 parts contain
Water,	78·2
Blood-globules,	13·5
Fibrin,	0·3
Albumen,	6·7
Salts,	0·9
Fatty matter,	0·4
	100·0

These numbers represent the average proportion of the constituents of the blood; age, the mode of life, and the state of health exercise a modifying influence on the composition of this fluid. Besides the solid and liquid constituents, the blood contains also several gaseous substances, viz.—*oxygen*, *nitrogen*, and *carbonic acid*.

Viewed through the microscope, the blood presents the appearance of a clear pale-yellowish fluid, in which are seen swimming about a multitude of minute red corpuscles, which are called *blood globules;* it is these which impart to the blood its red color. The coloring matter of the blood contains about 0·06 per cent of *iron*, which gives for the whole mass (30·5 lbs.,) about a quarter of an ounce. Part of the corpuscles contained in the blood, viz.—the *lymph corpuscles*, have no color.

If fresh blood is allowed to stand at rest for some time, it *coagulates;* that is, it separates into two parts,—a *solid* part which *floats* on the surface, and is called *coagulum*, or *clot;* and a watery *fluid* of a pale-yellowish color, which is called *serum*.

This separation is explained as follows:—On cooling, the fibrin of the blood coagulates in flakes, involving at the same time the globules, and constituting jointly with the latter the deep red-coloured coagulum which floats upon the serum. If the fresh blood be briskly stirred with the hand, or with a small brush, the fibrin will indeed also coagulate, but it will not involve, in that case, the blood globules, and the fluid will accordingly retain its red colour, and lose the property of coagulating. The fibrin of the blood (Chemistry, § 153) is in itself colorless, and adheres in the shape of white threads to the little brush with which the blood is stirred.

58. Upon heating the *serum* to ebullition, the albumen in it coagulates.

(Chemistry, § 152.) Boiling, therefore, changes the blood into a solid mass. When blood is mixed with a liquid turbid from the presence of foreign particles, the coagulating albumen of the blood envelopes these foreign particles, and effects thus the clearing of the liquid. Blood is therefore often employed in sugar-refining,—the process of clarification.

The salts which the blood holds in solution are principally *common salt*, (chloride of sodium), and *phosphate of lime*; which latter, as we have seen, constitutes the substance of the osseous tissue of the bones.

Besides these, the blood contains also a number of other matters, but in inappreciable quantities only. The most appreciable among these is *fat*, which is seen floating in the blood after cooling, in the form of small globules.

59. Thus we see that the blood contains all the materials of which the various parts of the human body consist, viz.—fibrin and albumen, which form the muscles and membranes; phosphate of lime, which constitutes the substance of the osseous tissues; fat and other substances, which are required in comparatively small quantities only, to form certain parts of the body, as, e.g., the cerebral substance. The blood is consequently the truly nutritive fluid of the body, out of which all parts of the latter are formed.

But to enable the blood to perform its nutritive functions, it was requisite that the means should be given of conveying it to every part of the animal economy. This is accomplished through the medium of the different vessels which constitute the vascular system.

1. The Arteries.

60. The arteries are tubes with highly elastic walls. They arise from the heart (see fig. 8), which is a hollow muscle situated in the cavity of the chest, and divided into several compartments.

The function of the arteries is to convey the bright red-colored blood to all parts of the body.

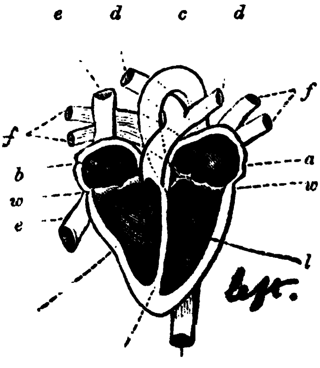
Hence the chief arterial trunk, which arises from the left ventricle (figs. 11 and 12), and is called the *aorta*, separates at once into several principal branches. Of these, the *carotid arteries* lying right and left of the neck, serve to convey the blood to the head; the *subclavian arteries*, right and left, to the upper extremities. At the point where these branches are given off, the aorta forms an arch, and descends on the left side of the vertebral column, giving off in its course branches to the different viscera, until ultimately it divides into the two *iliac arteries*, which convey the blood to the lower extremities.

All the main branches given off by the chief arterial trunk divide and sub-divide again, presenting ultimately in their last divisions a net-work of most minute vessels, which it requires the aid of the microscope to distinguish, and which on that account are called *capillaries* or *capillary vessels*. The capillaries merge immediately into the veins.

2. The Veins.

61. The veins also are tubular channels, but of laxer consistency than the arteries, which causes them to collapse when empty. As we have seen

in the preceding paragraph, the capillary terminations of the arteries merge into the minute channels which constitute the beginning of the veins. The venous capillaries speedily unite, forming larger tubes; these again combine to form several principal branches, which ultimately pour their contents into two chief trunks, called *venæ cavæ*, and which convey the blood back to the heart through the right auricle (see fig. 8).



8.

The venous blood is darker coloured than the arterial blood.

The throbbing motion or pulsation of the blood, dependent on the action of the heart, is lost in the capillaries, and no pulsation is perceptible, therefore, in the veins. Many veins lie pretty close to the surface, where the larger ones may be clearly seen through the semi-transparent skin, as blue lines. If the reflux of their contents to the heart is intercepted or impeded, they swell considerably, as may be readily shown with those on the back of the hand.

Small longitudinal incisions made in a vein, close again readily in a short time. In the practice of blood-letting, phlebotomy, or venesection, an incision is made, mostly in the large vein inside the elbow joint, with a sharp-pointed instrument, called a *fleam* or *lancet;* and when the quantity of blood required has been drawn, a little compress with a slight bandage over it, suffices to close the opening again.

3. The Absorbents and the Lymphatic Vessels.

62. The *lymphatic vessels* are found in almost every part of the body, both immediately beneath the skin and deeper seated. By the name of *lymphatic vessels* we designate a system of thin-walled transparent channels, which rise in exceedingly fine ramifications in the interior of various organs; these minute channels unite to form larger tubes, and then again combine to form several principal trunks, which ultimately pour their contents in several places into the veins.

The fluid contained in the vessels, the *lymph*, is generally transparent, and of a slightly yellowish color; the microscope reveals the presence in it of colorless globular corpuscles, somewhat smaller than the globules of the blood.

The lymphatic vessels in the intestines are of special importance. In § 53, we mentioned certain spongy cellular formations called *villi*, which are found in great numbers along the inner coat of the small intestine. From these villi rise numerous lymphatic vessels, whose sources are intimately connected with the digestive process. If the contents of these vessels are examined whilst the process of digestion is going on, they are found to present a turbid, whitish, milky appearance; the chief tube or canal, in which they ultimately unite, and which is called the *thoracic duct*, ascends

along the vertebral column, and finally pours its contents into the left subclavian vein, at the point where the latter unites with the left jugular.

The *villi*, from which these *lacteal* or *chyliferous* vessels rise, have unquestionably assigned to them as their special function the absorption of the nutritive juice (the *chyle*), produced in the digestive process; it is for this reason that the lymphatic canals rising from the villi, are termed also *absorbent* vessels. These canals unite in larger or smaller branches, which spread first through the mesenteric folds enclosing the intestines, and combine ultimately in the thoracic duct. On its passage from the villi to the veins the lacteal juice absorbed from the alimentary mass in the intestines gradually undergoes a series of changes in composition, which assimilate it more and more to the blood; it becomes charged with an increasing quantity of fibrin which imparts to it the property of coagulation upon cooling; and ultimately, as it approaches the subclavian vein, it acquires a rose tint, which deepens upon exposure to the air. Hence, it may with propriety be designated as colorless blood, and, indeed, the blood is always colorless in the greater number of the invertebrata.

CIRCULATION OF THE BLOOD.

63. The centre from which all the motion of the blood proceeds, is the *heart*.

Fig. 8 (see § 61), presents a section of this organ, which is somewhat simplified for the sake of clearness. The heart is divided longitudinally by a septum, *s*, into the *right* and *left ventricles* or *chambers*, *r* and *l*, and each of these has a *fore-chamber*, *a* and *b*. These fore-chambers are called *auricles*; they are separated from the ventricles by a flap or valve, *w*, through which each auricle may thus communicate with its ventricle.

The heart is a hollow muscle, which possesses the power of contracting and, accordingly, of diminishing the capacity of its inner cavity. Now, assuming this organ to be filled with blood, its contraction will forcibly impel that fluid into the tubular channels which open into the heart. Of these channels there are no less than eight, omitting the smaller ones, as we have done here in illustration of the organ. But the blood is not impelled into all of them upon the contraction of the heart, but only into two. The cause of this is to be sought in the presence of *valves* in the arteries and veins, and which, like the valves of pumps (Physics, § 105), open to the fluid pressing against one side, but close to the fluid coming from the opposite direction. Now, upon the contraction of the heart, the valves of the arteries, *c* and *d*, are forced open, and then permit the entrance of the blood into these arteries, whilst the valves of the veins, *e* and *f*, which are placed in an opposite direction, close, preventing thus the entrance of the blood into these veins.

However, the contraction of the heart, like that of every other muscle, is of limited duration, and is succeeded again by expansion; when the heart expands, the valves of the arteries close, whilst those of the veins open, permitting thus the return of blood to the heart. In this way, the contraction of the heart alternates incessantly with the expansion of that organ; we call this alternate contraction and expansion, the *pulsation* or *beating* of the heart. On an average, the heart beats 70 times in a minute; the pulsations

may be distinctly felt outside in the cardiac region of the heart, or they may be accurately counted from the corresponding pulsations of the radial artery in the wrist. In children, and in adults also in a state of excitement, and in many diseases, more particularly in fever, the pulsations often exceed 100 per minute.

64. The heart has two functions assigned to it, viz., on the one hand, it sends to all parts of the body the renovated blood, endowed with the properties that fit it for the nutrition of the various organs; and, on the other hand, it impels the dark-red blood, which it receives back through the veins, into the lungs, where it comes into contact with the air, which restores its bright-red color to it. The former function is called the *great* or *general circulation*, the latter, the *little* or *pulmonary circulation.*

65. The function of the *general circulation* of the blood is discharged by the left division of the heart. Upon the contraction of that organ, *bright-red* (*arterial*) blood is propelled into the *aorta*, *c*, whence it is diffused in all directions through the branches of the latter. Upon the expansion of the heart, the blood which in its passage through the body has changed its bright-red color to *dark-red*, is returned through the two venæ cavæ, *e*, to the right auricle, whence it passes into the right ventricle.

66. The *pulmonary circulation* goes on simultaneously with the general circulation. The *dark-red* blood is propelled from the right ventricle through the two branches of the pulmonary artery, *d*, into both lungs. Upon the subsequent expansion of the heart, the blood, which from its contact with the air in the lungs, has recovered its *bright-red tint*, is returned through the pulmonary veins, *f*, into the left auricle, whence it passes into the left ventricle, to be sent forth again into the general circulation, at the next contraction of the heart.

Thus the entire mass of the blood of the body is in incessant motion, alternating between the general and the pulmonary circulation.

67. The discovery of the circulation of the blood, one of the most important of those that have thrown some light on the phenomena of life, was made by the great Harvey, in 1619.

We have stated in § 60, that the capillaries of the arteries merge immediately into the capillaries of the veins. This may be clearly demonstrated by viewing under the microscope the transparent skin between the toes of a frog; the motion of the blood-globules through the arterial capillaries, and their passage into the venous capillaries may there be distinctly seen.

4. The Organs of Respiration.

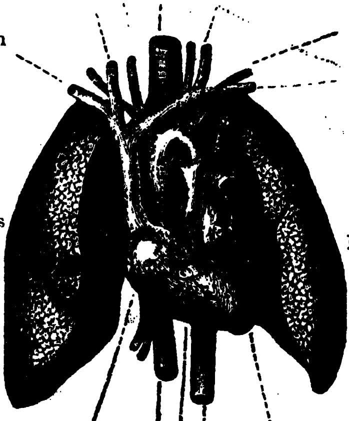
68. The *lungs*, together with the passages and channels leading to and from them, are designated as the organs of respiration.

Fig. 9 gives an illustration of these organs.

The substance of the lungs is made up of the exceedingly minute ramifications of the tubular canals, viz., the *windpipe*, or *trachea*, the *pulmonary artery*, and the *pulmonary veins*.

The lungs are a voluminous organ, consisting of two lobes or wings of pretty equal size, which envelope the heart on both sides, and, together with it, fill the thoracic cavity.

The office of the lungs is to bring the dark-red blood sent into them from the right ventricle of the heart, into contact with the air.



9. Lungs, heart, and principal vessels of man. (Comp. §§ 60 and 61.)

69. The *trachea*, or windpipe, *t*, which opens into the mouth, and communicates through the latter also with the nose, consists of about twenty hard cartilaginous rings, connected with each other by a membrane. At the upper end of the trachea is the *larynx*, which opens into the *pharynx* by an aperture or cleft, called the *glottis*.

To prevent the passage of any portion of food or drink into the windpipe, the glottis is protected by a kind of cartilaginous valve called the *epiglottis*, and which closes that aperture during deglutition; however, this valve opens when we breathe, speak, laugh, &c.; it will therefore occasionally happen, that when we speak or laugh whilst swallowing, solids or liquids, particles of food, &c., will get into the windpipe, when they create a violent irritation or spasmodic cough, by which they are ultimately expelled again from the trachea.

The trachea separates into two chief branches, which spread in every direction through the lungs in an infinite number of branches, terminating finally in minute vesicles filled with air, and which are encompassed by the minute ramifications of the pulmonary blood-vessels.

The lungs are accordingly an organ abounding in air; when removed from the animal body, and made to collapse by expelling the air, they may be restored to their original bulk by blowing air into them through the windpipe.

70. The act of respiration or breathing is accomplished by certain muscles expanding the chest, and creating thereby a species of empty space within the cavity of the chest, into which the air rushes from without,

through the windpipe. Upon the subsequent contraction of the thoracic muscles, a quantity of air, corresponding to the diminution of space resulting from that contraction, is expelled again through the same channel. A grown-up man takes in at every inhalation, on an average, 656·9 cubic centimeters, or 33 cubic inches of air. The number of inspirations amounts to about 18 per minute in an adult; in children it is greater. There are, on an average, 3·8 pulsations to every respiration.

Alteration of the Blood by the Respiratory Process.

71. We have seen, in § 65, that the blood, after completing the general circulation, is returned through the *venæ cavæ* into the right auricle of the heart, and that it passes thence into the right ventricle, and from this, at the next pulsation, into the lungs, through the two branches of the pulmonary artery.

In the lungs the blood undergoes an important alteration, from the action of the air upon it, with which it comes into contact in these organs. However, the contact between the blood and the air is not *direct*, the exceedingly fine membranes of the air-cells and of the capillaries intervening between them; what we have here is a similar penetration of these membranes, to that we have described in Botany, (§ 11), under the name of *endosmose*.

72. A comparison of the air inhaled into the lungs, with that exhaled again from these organs, shows us the result of this contact of the blood with the atmospheric air.

The air *inhaled* has the common temperature of the atmosphere, on an average about 59° Fahrenheit, and contains also the same amount of water. The air *exhaled* has the temperature of the body, about 99° Fahrenheit, and contains a corresponding quantity of aqueous vapour, which amounts, at each exhalation, to from 1 to $1\frac{1}{2}$ grains. The chemical change which the air exhaled has undergone in the lungs may be most clearly seen from the following table:—

Amount Present in the Air, of	Air Inhaled.		Air Exhaled.	
	In 100 Volumes by Measure.	In 100 Parts by Weight.	In 100 Volumes by Measure.	100 Parts by Weight.
Oxygen,	20·815	23·009	16·033	17·378
Nitrogen,	79·185	76·991	79·587	76·081
Carbonic Acid,	Traces.	Traces.	4·380	6·546
	100·000	100·000	100·000	100·000

This table, which is based upon the result of numerous observations and experiments, shows that the atmospheric nitrogen suffers no perceptible alteration or diminution in the respiratory process.

But the case is different with the oxygen of the atmosphere. This element is reduced by 4·782 volumes, which are found to be replaced by 4·38 volumes of *carbonic acid*. (Chemistry, § 53.) The respiratory power withdraws accordingly from the air a certain quantity of oxygen, and supplies to it instead a corresponding portion of carbonic acid.

Now, what becomes of the oxygen thus withdrawn from the air?

It combines with the carbonaceous matter of the dark-red blood, forming carbonic acid, which is then exhaled. The removal of this carbonaceous matter from the blood, restores to the latter its bright-red color. The bright-red blood is then returned to the left auricle, from which it passes to the left ventricle, to recommence its circulating course.

73. The body of an adult thus gives off with every respiration, a certain quantity of carbonic acid, amounting in the space of one hour to about 44 grammes ($1\frac{1}{2}$ ounce). In these 44 grammes of acid are contained 12 grammes of carbon. The body of an adult gives accordingly off, in the process of respiration, 288 grammes (9 ounces 2 drachms) of carbon, in the course of 24 hours.

Hence it follows, as a natural consequence, that we must supply to the body the requisite amount of carbon to support the respiratory process. Now, this is in fact done by the vegetable and animal substances, which we partake of as food, and which all contain carbon.

A considerable portion of the food daily consumed entirely goes to support the respiratory powers. With every breath we draw, the body loses a certain amount of weight, which loss must be replaced, or the body will speedily suffer want. A starving individual is exhausted through the respiratory process; if we were able to stop that process for days, weeks, or months, we might live all that time without food. There are some animals, such as snakes and toads, for instance, which remain for many weeks without perceptible respiration, and it is a well-known fact that these can for a similar and even for a longer period of time dispense altogether with food. In the hybernating animals, the respiratory process is suspended during the period of torpor, and they accordingly require no food in that state.

Animals that pass the winter in a dormant state, like the badger, the marmot, and many others, continue to breathe, but slowly and feebly only. Still even this slow process consumes a considerable portion of the body, as is evident from the lean appearance which these animals present in spring, contrasted with the sleek rotundity of body that marked them just before they fell into their hybernating trance. If the winter's sleep continued much longer, these animals would be unable to outlive it.

74. Chemistry tells us (§ 22), that the combination of oxygen with other elements is always attended with the disengagement of heat, and that the amount of heat evolved is the greater, the larger the quantities of the combining elements. Everybody knows that the burning of a piece of charcoal or pit coal in the air, yields a certain amount of heat, which may be applied to various purposes.

Now, as has been shown above, the respiratory process is simply a process of chemical combination taking place in the body, between the carbon of the latter and the oxygen of the atmosphere; this process must accordingly be attended with disengagement of heat. Now, this is indeed the case, and it may even be safely affirmed that one of the essential ends of respiration is the generation of heat, which is communicated more immediately to the blood, and is then by the rapid and universal diffusion of that fluid, conveyed to every part of the body. The heat of the blood, and accordingly that of every part of the body, is in the adult about 97° to 98° Fahrenheit;

it is higher in children, and lower in persons of advanced age. In the other mammiferous animals, it is pretty nearly the same as in man. It is somewhat higher, however, in the denizens of the polar regions; in the birds it reaches 108° Fahr. On the other hand, most of the fishes, the reptiles, and the invertebrate animals have the temperature of the surrounding media.

Physiological Conclusions and Inferences deducible from the Facts and Statements given in the preceding Paragraphs, on the Digestive, Circulatory, and Respiratory Organs.

75. From the facts and statements given in the preceding sections on the organs of digestion, circulation, and respiration, a number of inferences and conclusions may be drawn, explanatory of several of the phenomena of life, among the most important of which are those of nutrition, since upon a proper comprehension of the nutritive process depends not only the preservation of the human race, but also, in a great measure, the moral and intellectual status of man.

76. If we compare the nutrition of man and of the animals with that of plants, we find an essential difference, not only in the respective manner of the absorption and assimilation of the alimentary material, but also in its nature. In the vegetable kingdom the nutritive function is not assigned to one specific organ, as is the case in the animal; we see almost the entire surface of the plant, viz., the root and leaves, adapted for, and engaged in, the absorption of the nutritive elements, whereas animals take their food only through one single aperture, the mouth.

The difference between the plant and the animal is much more striking still in the nature of the nutritive substances upon which they separately subsist. The plant feeds entirely on *inorganic* matter. Water, carbonic acid, and ammonia, the three principal aliments of the plant (Botany, §§ 88, 99), are generated by the influence of the general power of nature upon the constituent elements of our terrestrial sphere; they are inanimate, inorganic, matters, just as much as minerals are; they differ totally from the parts of the plant which they aid to form.

The plant possesses accordingly the faculty of absorbing inorganic elements, of assimilating them, and of combining and forming them into organic bodies. Out of water, carbonic acid, and ammonia, the plant forms woody fibre, starch, sugar, vegetable albumen, and many other constituents of the plant. (Chemistry, §§ 119—157.)

77. This faculty the animal lacks. It cannot form its albumen, its muscular fibre, or its fat, out of carbonic acid, ammonia, and water. It requires, therefore, some agent to convert the elements indispensable to its existence, into organic, assimilatable forms; this function the plants perform.

Indeed, if we compare the chemical composition of the albumen, casein, fibrin, and fatty matter of plants (Chemistry, § 150) with that of the substances bearing the same name in the animal body, we see clearly that the animal which consumes the plants finds in them ready formed all the compound organic matter which it requires for the construction and development of the various parts of its own body.

78. The digestive and assimilative processes in the animal are therefore more simple and more easily intelligible than they are in the plant. The

animal has not to *form* its muscular fibre, fat, &c., out of the elements supplied to it; the digestive function in it is confined to the *solution* of those matters which it finds ready formed in the plant, and to their conveyance to the parts where they are required, and their appropriation to the nutrition of these parts.

This applies still more strongly to animals living on the flesh or blood of other animals. These feed obviously on the identical materials that form their own body, and the digestive function in them is confined to a mere transformation of the food.

It is a well-known fact, that we find digestion the easier the more the food partaken of contains the materials that constitute our own body. The digestive organs of the *ruminating* or herbiverous animals, are in many respects arranged differently from those of the carnivorous animals. The flesh which the latter consume is almost wholly assimilatable; digestion proceeds therefore in them more rapidly, the meals are comparatively smaller, and the excretion of useless matter is much less considerable than is the case in the herbiverous animals.

The hay and grass on which the ox feeds contain but a small proportion of albumen, fibrin, and fat, that is, of the materials most required for the nutrition and development of the animal; whereas, on the other hand, they abound in woody fibre, a substance perfectly useless in the economy of the animal. The ox consumes therefore immense quantities of hay and grass, but it eliminates again the greater part of its meals as inapplicable to the purposes of nutrition. It requires, moreover, a longer time for the solution of the nutritive materials, and the separation of the woody fibre, than the carnivorous animal requires to digest its food, which is so perfectly analogous to the substance of its own body. In the true herbivorous animal, the food remains therefore a long time in the stomach; nay, after being soaked for a time in a particular part of the latter, it is returned once more to the mouth to be again chewed and mixed with saliva, to make it better adapted for the digestive and assimilative processes. It is from this singular property of chewing the food over again (*rumination*) that these animals have received the name *ruminantia*. The intestinal canal of beasts and birds of prey, of the cat and the kite, for instance, is very short.

79. Under ordinary circumstances, the weight of the body of an adult neither increases nor decreases. There are of course exceptions, as, for instance, in cases of excessive formation or accumulation of fat, or of wasting from sickness and disease; but as a general rule, from the time that the body has attained its full development, all the alimentary substances ingested have simply to replace the materials expended in the various vital processes, but not to increase the bulk of the frame. The weight of the solids and liquids consumed by an adult in the course of a twelvemonth, must therefore exactly equal that of the various secretions given off by the body in the same period of time.

Independently of that portion of the food which, being altogether unfit for the purposes of nutrition, is ejected from the body in solid or fluid form, the principal excretions of the body which we have to take into account here, are the cutaneous perspiration and the exhalation from the lungs.

80. All kinds of food taken into the body are not used for the same pur-

pose in it. Starch, sugar, gum, alcohol, and fat, are substances which we very often partake of: now, none of these substances contain nitrogen; they cannot serve, therefore, to form any part of the body containing that latter element, such as albumen and the muscular fibre. Neither man nor the animals can sustain life upon these substances alone. They serve principally to maintain the respiratory process; supplying the carbon, which is removed from the body by that process; and as this is attended, as has been shown in § 74, with a constant disengagement of heat, starch, gum, sugar, alcohol, and fat, may appropriately be termed *calorific substances*, or the *fuel* of the animal economy.

81. The formation and maintenance of the nitrogenous parts of the body require the ingestion of nitrogenous substances, such as vegetable and animal *albumen*, *fibrin*, and *casein*. Only those articles of food which contain one or several of these substances, are able to supply the blood with the constituents required to effect the increment or renovation of the different parts of the body. These nitrogenous aliments are, on that account, technically termed *plastic* aliments, or, more familiarly, *nutritive* substances. (Chemistry, § 150.)

82. Now, supposing we were to feed an animal entirely on pure starch and albumen, we should indeed supply it with the materials requisite to maintain the respiratory process, and to form the muscular fibre; yet, nevertheless, the animal would not continue long in the enjoyment of health upon this food, and would ultimately perish, because starch and albumen contain neither *phosphate of lime*, which serves to form the osseous tissue, nor chloride of sodium (common salt), which is indispensable for the elaboration of the gastric juice.

If cattle be fed exclusively upon substances containing little or no lime, such as oil-cakes, turnips, and the potato-wash refuse of distilleries, the animal does not find in these substances the material requisite for the formation and maintenance of its bones, and these remain weak, whilst the rest of the body increases disproportionately, so that the feeble bones are ultimately unable to bear the weight resting on them, and break under it. This dread infirmity, which is termed "*softening of the bones*" (*mollities ossium*), cannot affect cattle amply supplied with clover and hay, which substances abound in lime salts. (See Botany, § 98.)

It is a well-known fact that fowls and pigeons eagerly seek and greedily devour extraneous substances, such as mortar, for instance. (Chemistry, § 79.) They require such substances the more, as they have to enclose the eggs laid by them within a calcareous shell. Fowls will sometimes lay eggs enclosed in a soft membranous bag instead of a shell; this is a sure sign of deficiency of lime in their food.

In the same way man and other animals seek for aliments containing *salt* (chloride of sodium), which is indispensable in the digestive process. All natural springs hold this important body in small quantities in solution, and it is present also in many parts of plants, and in many animal substances. But over and above the quantity thus placed at our disposal, we add salt also as a condiment to most of our dishes. That this body serves to promote the digestive process, has been fully recognised from the earliest times.

83. Now it follows from the preceding observations, that those alimentary

substances are best adapted for food which contain not only *caloric* or *heat-generating* constituents, but also *plastic* or *nutritive* constituents, and likewise materials serving for the formation and maintenance of the osseous frame. Substances of this kind are more particularly the cereals, pulse, milk, flesh mixed with fat, eggs, and blood.

The following tabular view of the chemical composition of these dietary articles, will show their respective relative importance as articles of food:—

100 Parts by Weight of the following Alimentary Substances contain—	1. Non-nitrogenous or Calorific Substances.			2. Nitrogenous or Nutritive or Plastic Substances.			3. Water, and Substances supplying Material for the Osseous Tissue.	
	Starch.	Sugar.	Fat.	Albumen.	Fibrin.	Casein.	Phosphate of Lime.	Water.
Rye	40	2	...	...	8	...	0·01	10
Wheat	74	4	...	...	11	...	0·08	10
Barley	32	5	...	...	5 (?)	...	0·24	11
Rice	85	Trace.	Trace.	..	3·6	...	0·4	6
Potatoes	15	Gum, 4	...	1·4	...	...	...	75
Beans	42	Trace.	0·7	...	...	18–20	1·0	23
Peas	42	2	...	...	...	18	2·0	13
Flesh	...	...	...	...	23	...	...	77
Milk	...	4	3	...	...	5	0·5	87
Blood	...	...	0·4	6·7	13·8	...	0·9	78
Albumen	...	...	...	12–14	...	..	...	88–86
Yolk of Egg	...	...	29	7	..	...	...	54

See Chemistry, § 150–154.

84. As appears from this table, the cereals contain not only materials to support the respiratory process, but also the nitrogenous fibrin, which serves to make blood, and phosphate of lime for the formation of the osseous tissue. Bread and water in plenty will, therefore, suffice to support an individual not overtaxed with hard work. Rye and barley contain from 18 to 24 per cent of woody fibre, which cannot be turned to account in the animal economy, and are therefore inferior to wheat in fibrin and starch. But wheat again contains too little lime salts; so little indeed, that a young pigeon fed exclusively upon it is speedily affected with softening of the bones. In the cereal grains, and more especially in wheat, the nitrogenous part is contained principally in the outer layers, the innermost layer containing almost pure starch. Therefore, the more carefully the outer layers are removed to obtain flour of a whiter aspect, the less nutritive will that flour be.

In rice and potatoes we find very little real nutriment to a considerable amount of starch. Large quantities of these aliments must consequently be ingested to supply the requisite amount of nitrogen to the body. And, indeed, it is a well-known fact that the Irish peasantry consume, or rather used to consume, immense quantities of potatoes, and that negroes make an enormous consumption of rice. The consequence of this is that an excess of starch is brought into the organism, of which a portion at least is rejected unaltered along with the excrements.

Peas and beans are the most nutritious of vegetable substances, on accoun more especially of the considerable proportion of nitrogenous *casein* which they contain. Flesh, which consists entirely of fibrin, has this advantage

over peas and beans, that it is more easily digested than the latter. By itself, flesh does not contain sufficient carbon to support the respiratory process; as it is, however, usually mixed with fat, this deficiency is a matter of but little importance.

But in no dietary substance do we find a more favourable combination of calorific and nutritive substances, and materials for the formation of the osseous tissue, than in *milk*, as that substance contains *sugar*, *fat*, *casein*, and the requisite salts in solution. Milk is therefore also peculiarly adapted to furnish the principal article of food to the young of man, and many animals, during the period of development.

85. As all elementary substances injected requires to be reduced to the fluid state, the body must constantly be supplied with a certain amount of water, to effect the solution and conveyance of nutritive particles. This water is partly contained in the food, and partly taken in guise of drink. Of all elementary substances milk alone furnishes, along with the nutritive constituents, also the requisite quantity of water.

Like the plant, the animal body imbibes a much larger quantity of water than is required for internal consumption; a portion of the water is accordingly always given off again, and this by three different outlets; it may be assumed, that of the total amount of water removed from the body, one-fifth passes away by the lungs, and one-fifth through the skin, the remaining three-fifths leaving the body in the urinary secretion.

86. The renal artery conducts the blood, in its circulatory courses through the *kidneys*, two bean-shaped glandular organs, situated in the abdomen. The function of these organs is, to withdraw from the blood passing through them a portion of its superfluous water, and also several excretory matters held in solution, and which the blood, in its passage through the body, has removed from various parts, and more especially from the muscles. The *urine* thus excreted in the kidneys is then conveyed to the bladder, whence it is finally ejected from the body.

87. The quantity of food required for the support of an individual depends upon the temperature and the hygroscopic state of the atmosphere, and also on the amount of muscular exertion on the part of the individual. Man requires the larger amount of food, the colder and moister the climate in which he lives. This is easily explained: cold and moisture have a tendency to abstract a larger amount of caloric from the animal body than is given off by the latter in warmer climes; and the loss of caloric then sustained must be replaced by a more active respiration and increased generation of heat.

It is a well-known fact that the inhabitants of hot countries require considerably less food than those of temperate and cold climates, and that the denizens of the frigid zones consume more, particularly large quantities of calorific substances (§ 80). The Laplanders, for example, drink train oil in large quantities. The prodigious appetities of the inhabitants of the far north is to be looked upon, therefore, simply as a necessary consequence of the natural conditions of nutrition, and by no means to be accounted as gluttony. When amply supplied with food, man can support the most intense cold.

88. In every muscular motion a portion of the substance of the muscle

moved is used up or spent. This expenditure of substance must be replaced, if the muscle is to retain the power of motion. Muscular movements can, therefore, endure only for a time; an incessant motion would be attended with an equally incessant consumption of substance, which would speedily wear out the body. Long-continued exertion and expenditure of muscular force and substance is followed in all animals by a feeling of lassitude, succeeded by repose or *sleep*. In man the average time of muscular exertion is 17 hours per day, the remaining seven hours are generally spent in sleep. During the period of repose, the muscles receive a sufficient supply of fresh fibre for the consumption of the next day. Now, it will be quite obvious to every one that people who are called upon to make great bodily exertions, and who expend accordingly a large amount of muscular substance, require a considerable proportion of alimentary matters containing the elements of the muscular fibre, such as bread, meat, pulse, cheese, and similar articles.

C. THE ORGANS OF THE SENSES.

89. In the organs of the senses we find several of the organic formations such as bones, muscles, nerves, and blood-vessels, combined; these organs may accordingly, in this respect, be termed compound organs.

We distinguish five different organs of the senses, viz., the skin, the tongue, the nose, the ear, and the eye.

1. The Skin.

90. The skin is the organ of *feeling*. It covers the whole surface of the body. It consists of three different layers or membranes, viz., the *skin proper* or the *vascular layer*, the *muscular layer*, and the *cellular layer* or *cellular tissue*.

a. The *skin proper* forms the external covering of the body. It is composed again of three distinct layers, called respectively, the *cuticle* or *epidermis*, the *rete mucosum*, and the *cutis*, or *chorium*, or *dermis*.

The *epidermis* is a thin semi-transparent membrane, void of sensation. It is readily perforated with the point of a needle, or some other sharp instrument, and may thus be lifted up from the underlaying *dermis*. In certain parts of the body, when the cuticle is exposed to frequent and severe pressure, it gets thickened, and forms *calosities* and *corns*.

The *pores* are numerous minute depressions or apertures in the cuticle; the *hairs* take root in similar depressions. We shall have occasion to return to this part of the subject.

The *rete mucosum* lies immediately beneath the cuticle, of which, properly speaking, it simply forms the lowest or innermost layer, which still retains its original moisture. This layer encloses the pigmentary matter, which imparts to the skin its color or complexion, and differs in the races or nations of different climes, being black or swarthy in the negro, copper-colored in the American Indian, brown in the Malay, yellow in the Chinese, colorless or pale in the Caucasian race. In the latter the red blood-vessels of the lower cuticular layer are seen through the upper layer, and impart thus to the surface a red coloration or complexion, as is apparent, more especially, in the cheeks and lips.

The *cutis vera*, *dermis*, or *chorion*, forms the most essential part of the *vascular skin;* it consists of a thick tough layer of fibres, vessels, and nerves, closely interwoven. It is this part of the skin, which, freed from the upper layer and the hair, is used as leather.

A magnifying lens shows on the surface of the *cutis* an infinite number of minute *papillæ*, consisting of bundles of fine nervous filaments, which terminate in them, and constitute the seat of tactile sensation. In certain parts of the body, such as the palm of the hand, and the tips of the fingers, they may be seen in regular rows of linear elevations.

91. *(b.)* The *muscular layer* or *fibrous membrane* consists of a thin layer of muscular fibres lying under the cutis; in man, this fibrous membrane is met with only in certain parts of the body, such as the head and neck, for instance; but in many of the mammiferous animals, as in the hedgehog, for instance (compare § 29), it is spread all over the outside of the body.

(c.) The *cellular layer* or *cellular tissue* forms the third—in parts lacking the fibrous membrane, the second—and innermost layer of the integumentary system. It consists of loose tissue filled with fat, and is sparingly developed in lean people, but amply in corpulent persons.

92. To the skin belong claws, the hair, the nails, scales, feathers, and horns.

The hairs are inserted with roots or bulbs in depressions of the cuticle. They grow only at the roots, having neither nerves nor vessels, and may thus be cut off, without causing the slightest feeling of pain. The hairs are hollow tubes, filled with a coloring fluid.

The nails, scales, and feathers, may be regarded in the light of conglomerations or agglutinations of numbers of strongly-developed hairs. These formations are also void of sensation, and grow only at the roots. The same applies also to the horns; true, in many animals the structure of the horns is not clearly apparent, but a careful examination of the horn of rhinoceros, for instance, shows most convincingly that that part consists only of agglutinated hair. The several cuticle formations correspond also in their chemical composition; 100 parts of them contain 51 parts of carbon, 7 of hydrogen, 18 of nitrogen, and 24 of oxygen, along with a small portion of sulphur. On account of the large proportion of nitrogen in them, these substances are extensively used in the manufacture of Prussian blue. (Chemistry, § 92.)

93. The numerous capillaries diffused through the vascular skin bring the blood in them into very close contact with the atmospheric air, which indeed is kept from immediate contact with that fluid only by the thin walls of the capillaries and by the epidermis. But as membranes are not absolutely impermeable to fluids, a portion of the blood in the capillaries is being constantly exhaled through the walls enclosing it, and passes through the pores of the skin in the form of what is termed *cutaneous exhalation* or *perspiration*.

The perspiration is composed chiefly of water. It contains, however, many volatile substances marked by a peculiar odor. The quantity of the cutaneous exhalation amounts to one-fifth of the fluid excretions of the body. Cutaneous exhalation is essential to the health of the body; impaired activity of the skin is always injurious to the body. The total suppression

of the cutaneous exhalation in an animal by closing the pores of the skin with a coat of varnish, leads speedily to the death of the animal experimented upon. Increased cutaneous secretion is produced by all causes which excite a copious flow of blood to the skin, such as a high temperature, powerful exertion, warm drinks, &c. The skin of the carnivora has no pores; consequently these animals do not perspire, and need accordingly a smaller supply of water than the animals with an active cutaneous excretion.

2. The Tongue.

94. The tongue is the organ of the sense of *taste*. This organ may be regarded in the light of a separate and highly-developed portion of the skin, in which the papillæ are distinctly visible, and the fibrous membrane is present in the shape of two strong muscles. The latter gives to the tongue considerable mobility, which enables that organ to afford essential assistance in the mastication and deglutition of the food, and also to alter the form of the buccal cavity in an infinite variety of ways, giving rise thereby to certain modifications and modulations of the vocal emissions, which it would otherwise be altogether impossible to produce. In this respect the tongue is to be considered also as a most essential part of the organ of speech.

Only such bodies as are soluble in water affect the organ of taste. Perfectly insoluble bodies, such as charcoal, flint, &c., are termed *insipid* or *tasteless*. The gustatory faculty of the tongue is aided by the contiguous salivary glands (§ 47), which secrete the saliva, an aqueous liquid, whereby most of the substances put into the mouth are partly dissolved, and are thus brought into a proper form to the perception of the *papillæ*.

The tongue is formed in a visible shape in the *vertebrate*, and also in many of the *invertebrate*, animals. In many of the lower animals this organ is wanting; still, we must not infer from the absence of the tongue in them the absolute want of the sense of taste. The selection made by such animals of particular kinds of food, is a sufficient refutation to any supposition of the kind; it is well known, for instance, that caterpillars will only feed on certain plants, passing by and rejecting others.

3. The Nose.

95. The nose is the organ of the sense of *smell*. The most essential part of this organ is the ethmoid bone, which consists of a great many thin convoluted plates, and is covered with the *pituitary membrane*. The latter is kept continually moist by the secretion of a mucus, called the *nasal mucus*. This condition of the pituitary membrane is most essential for the perception of odor; dryness of the membrane, or over-abundant secretion of mucus, are attended equally with temporary loss of the sense of smell. The pituitary membrane, by its numerous convolutions, presents in a narrow compass a surface of several square feet to the influence of odoriferous substances.

Substances only which can assume the gaseous state are perceptible to the sense of smell. All other bodies are termed inodorous. It is truly astonishing what exceedingly minute quantities of corporeal matter are still perceptible to the sense of smell. A grain of musk in a room suffices to scent the latter, and even the whole house, and yet the most delicate balance fails to detect the slightest loss of weight in the musk. The nose is there-

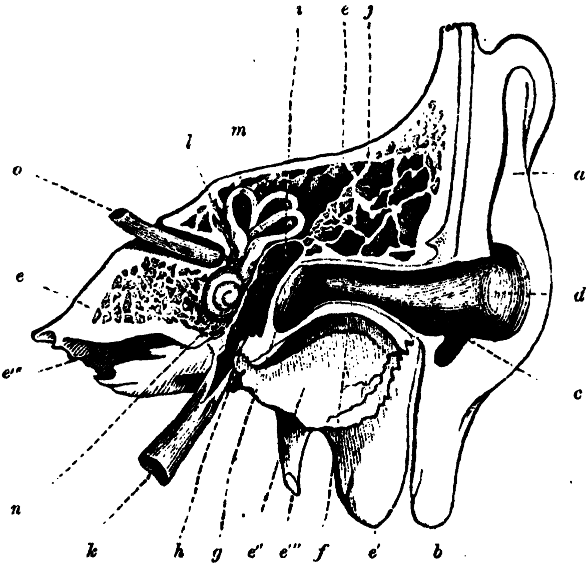
fore a most important organ, which reveals and indicates to us the presence of many things of which our senses fail to give the slightest intimation. It is a well-known fact that savages scent the smoke of a fire at many miles' distance; that camels in the parched desert smell the water at considerable distances, and hasten to reach it; that the hound, guided by the scent alone, will follow the tracks of the game, or of their master.

96. In man, the nasal cavity opens in the mouth by two passages placed behind the palate; this arrangement enables us to breathe also through the nostrils. We find the same arrangement in the mammiferous animals, in the birds, and in the reptiles, but not in fishes.

The lower orders of animals have no sensible organ of smell, yet they are not all of them totally destitute of this sense: for example, the carrion-beetle evidently scents the decomposing bodies on which it preys, and it is a well-known fact that moths avoid strong smelling substances.

4. The Ear.

97. The ear is the organ of the sense of *hearing*. This organ exists always in duplicates. It consists of the outer ear and the inner ear. (See fig. 10.)

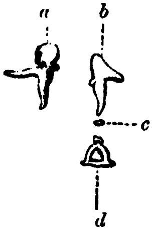


10.

[This figure represents a vertical section of the auditory apparatus, of which the interior parts are slightly magnified to render them more distinct: *a*, the external ear; *b*, the lobe of the ear; *c*, the little eminence called antitragus; *d*, the conch of the ear, the end of which is continuous with the external auditory meatus, *f*; *ee*, portion of the temporal bone called the petrous portion, in which is lodged the auditory apparatus; *e'*, the mastoid process of the temporal bone; *e''*, portion of the glenoid fossa of the temporal bone, in which the lower jaw is articulated; *e'''*, the styloid process of the temporal bone, serving for the attachment of the muscles and ligaments of the os hyoides; *e'''*, extremity of the canal which the internal

carotid artery passes through to enter the cavity of the cranium; *f*, the external meatus auditorius; *g*, the membrana tympani; *h*, the cavity of the tympanum from which the small bones have been removed; *i*, opening leading from the cavity of the tympanum to the cells in the petrous bone; in the inner wall of the cavity of the tympanum are perceived the two openings called respectively fenestra ovalis and fenestra rotunda; *k*, Eustachian tube, leading from the tympanic cavity to the back of the pharynx; *l*, the vestibule; *m*, semicircular canals; *n*, the cochlea; *o*, the auditory nerve.]

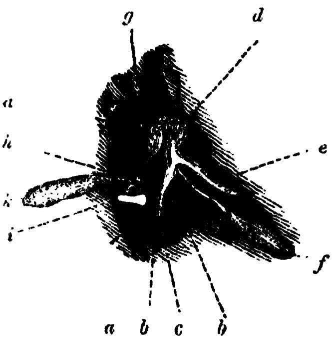
The outer ear (*a*) contracts into the outer auditory duct or passage (*meatus auditorius externus*), (*f*), which is closed by a highly elastic membrane, the *membrana tympani*, or *drum of the ear* (*g*), behind which lies the cavity of the tympanum (*h*). This cavity is connected with the mouth by the *Eustachian tube* (*k*). This connection explains the reason why persons hard of hearing generally listen with open mouth. The cavity of the tympanum holds a series of small bones, to which certain names have been given, in accordance with their respective shapes, viz. the *hammer* or *malleus* (fig. 11, *a*, and fig. 12, *c*, *d*, *e*), the *anvil* or *incus* (fig. 11, *b*, and fig. 12, *g*), the *os orbiculare* (fig. 11, *c*, and fig. 12, *h*,) and the *stirrup* or *stapes*, (fig. 11, *d*, and fig. 12, *i*). The labyrinth (see fig. 10) is composed of the *cochlea* (fig. 10, *n*); the *vestibule* (fig. 10, *l*), with the *fenestra ovalis*; and the *semicircular canals* (fig. 10, *m*). The vestibule and cochlea are filled with an aqueous liquid, through which the filamentous expansions of the auditory nerve (fig. 10, *o*), are diffused.



11.

a. Malleus.
b. The Incus.
c. Os orbiculare.
d. The stapes.

We have no very accurate knowledge of the exact nature and functions of these several component parts of the ear. This much is known, however, that the waves of sound are collected by the outer ear, and conveyed to the membrane of the tympanum, which is thereby set in motion; this motion is communicated through the small bones to the fluid of the labyrinth, and thus to the expansions of the auditory nerve.



12.

[This figure represents the external wall of the tympanic cavity, the membrana tympani, the small bones of the ear, and their muscles, the whole magnified; *a a*, border of the tympanic cavity; *b*, the membrana tympani; *c*, the manubrium of the malleus, with the end resting upon the membrane of the tympanum; *d*, the head of the malleus articulating with the incus; *e*, process which rises below the neck of the malleus, and enters the glenoid cleft of the temporal bone: to the extremity of this process the anterior muscle of the malleus is attached; *f*, inner muscle of the malleus; *g*, the incus, resting its horizontal branch against the walls of the tympanic cavity, the vertical branch articulating with *h*, the os orbiculare; *i*, the stapes, with the apex articulating with the orbicular bone, and the base resting upon the fenestra ovalis; *k*, the muscle of the stapes.]

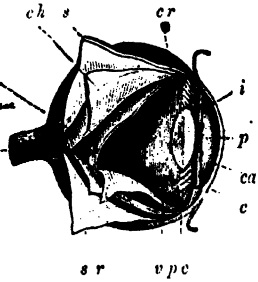
The most essential part of the organ of hearing is the auditory nerve. Therefore lesions of the membrane of the tympanum, and derangement of the small bones, do not necessarily entail total loss of hearing. Nay, in many animals, in crabs, for instance, the organ of hearing consists simply of a vesicle filled with fluid, and on which the auditory nerve is expanded.

The mammiferous animals alone have a visible external ear. In birds there is a simple aperture, and in fishes and reptiles this is covered over by a membrane. In the lower orders of animals an organ of hearing is only exceptionally met with.

5. The Eye.

98. The eye is the organ of the sense of *sight*. The essential part of the eye is called the eye-ball. Fig. 13 gives a lateral view of it. Proceeding in our contemplation of the organ from the inner to the outer parts, we find that the inner part consists of a transparent ball, formed of a gelatinous substance, called the *vitreous humor*, *v*. This ball is enveloped in three coats, the innermost of which is the *retina*, *r*, on which the optic nerve, *n*, expands; this is enclosed by the *tunica choroides*, *ch*, so called from the numerous blood-vessels traversing it, and which impart a red tint to it. The anterior part of it joins the brown- gray- or blue-colored *iris*, *i*; in the centre of the iris is an aperture, called the *pupil*, *p*, and beneath the iris are the *ciliary vessels*, *pc*. The whole of the inner surface of the tunica choroides is covered with a black pigment, so that the eye presents a small *camera obscura* or dark chamber, into which light falls only through the pupil. Occasionally the pigment is wanting, in which case the ciliary vessels lying beneath shine through the transparent membrane, and impart a red color to the eye. Human beings with eyes of this kind are called *Albinos;* they cannot well bear the light; this is the case also with white rabbits, mice, &c., which have red eyes.

is covered
of a membrane
called the
hyaloid.



13.

The third and last, or outer coat, is called the *sclerotica*, *s*. This is a very strong white membrane, somewhat resembling porcelain in appearance. From its great solidity, it affords considerable protection to the eye. The anterior part of it, called *cornea*, *c*, is somewhat more convex than the rest, and is perfectly transparent. The space between the cornea and the iris constitutes the anterior chamber of the eye, *ca*, which is filled with a colorless transparent fluid.

Almost immediately behind the pupil lies the *crystalline lens*, *cr*, which is formed of a gelatinous perfectly transparent substance, a little more firm and solid than the vitreous humor.

These several parts of the eye may all be clearly seen in the dissection of a bullock's eye; the inspection of the crystalline lens removed from the latter, will show that it possesses the properties of a common convex lens of glass or crystal. The structure and functions of the eye (the *sight*), are in fact in every respect in accordance with the optical laws explained in the physical part (§ 166).

II. CLASSIFICATION AND DESCRIPTION OF ANIMALS.

99. The description of the animals amounts, properly speaking, simply to a constant comparison of their bodies, with the body of the most perfectly

developed and the most highly organised of all animals—*man*. We have therefore given, in the preceding sections, a brief outline of the anatomy and physiology of the human body. The division of the various animals into classes, &c., is based upon analogous deficiencies in the number, or analogous imperfections in the development, of their respective organs.

We call an animal the more perfect, and place it the higher in the scale of our classification of the animal kingdom, the more its organs approach in number and development to those of man.

Of course, this principle of classification has also its difficulties, arising principally from the circumstance that the organs of many classes of animals differ widely in form, shape, and structure, from the corresponding organs in man. Thus, for example, the respiratory apparatus in insects consists of simple air tubes, or elongated air cells traversing the body, and which resemble the human lungs in no one point, except in the nature of the functions which they have to perform.

From these deviations in form and structure from the common type, considerable uncertainty prevails often as to the exact nature of certain organs in some of the divisions of the animal kingdom, and zoologists are not always agreed upon the rank to be assigned in the table of classification to certain classes of animals. Thus, for instance, some rank the molluscs above the insects; others place the latter higher in the scale. However, upon the whole, these differences of opinion are not very material; at all events, for our purpose here it is of greater importance to learn the characters of the different classes of animals than to determine the rank to which they are respectively entitled in the table of classification.

At present, about 48,870 *genera* of animals are known, which have been more accurately described; but it may be assumed that the number actually existing is not fewer than 88,000; and the addition of the extinct genera discovered in petrefactions swells the number to above 100,000. It has been already stated (in § 25) that we divide the whole animal kingdom into two principal groups or sub-kingdoms, viz., animals that have no vertebral column, *invertebrata*; and animals with a vertebral column, *vertebrata*.

Each of these two sub-kingdoms is divided into *classes*; the classes again are divided into *orders*, and these latter into *families* or *tribes*; these again into *genera*, the genera into *species*, and the latter finally into *varieties*.

It is obvious that even a mere general description of this immense number of living creatures would far exceed the limits of works of much larger bulk and higher pretensions than this elementary treatise on the subject. It will be readily understood therefore that we must confine ourselves here to mere outline indications of the general characters of the principal classes and orders, and to a simple enumeration of some of the more important animals in them as types and examples.

The following tabular view embraces the whole animal kingdom arranged in classes and orders:—

Tabular View of the Animal Kingdom.

A.—Vertebrata.

Brain and spinal marrow enclosed in bony cases; red blood; vascular system, consisting of arteries, veins, and lymphatic vessels.

Classes.	Orders.
I. *Mammalia.* Red, warm blood; heart with two auricles and two ventricles; lungs; producing their young alive, and nourishing them with their milk; body hairy, with few exceptions. Number of known genera = 1,500.	1. Bimana. 2. Quadrumana. 3. Cheiroptera. 4. Carnivora. 5. Marsupialia. 6. Rodentia. 7. Edentata. 8. Pachydermata *seu* multungula. 9. Solidungula. 10. Ruminantia. 11. Pinnipeda. 12. Cetacea.
II. *Aves (Birds).* Red, warm blood; heart with two auricles and two ventricles; lungs; lay eggs; body covered with feathers; anterior members, wings. Number of known genera = 6,000.	1. Raptores. 2. Insessores. 3. Rasores. 4. Cursores. 5. Grallatores. 6. Natatores.
III. *Amphibia (Reptiles).* Red, cold blood; heart with two auricles and with a simple or imperfectly divided ventricle; breathe through lungs, and partly through gills; lay eggs; skin scaly or naked. Number of known genera = 1,500.	1. Chelonia—turtles. 2. Sauria—lizards. 3. Ophidia—snakes. 4. Batrachia—frogs.
IV. *Pisces (Fishes).* Heart with one auricle and one ventricle; red, cold blood; breathe through gills; lay eggs; have members adapted for swimming (fins), and a scaly skin. Number of genera = 5,000.	1. Plagiostomi. 2. Eleutherobranchi. 3. Cyclostomi. 4. Pectognathi. 5. Lophobranchi. 6. Malacopterygii. 7. Acanthopterygii.

Tabular View of the Animal Kingdom—*continued.*

B.—Invertebrata.

No brain nor spinal chord; nervous centres or ganglia, connected by medullary chords; or a simple nervous filament; or no discernible traces of a nervous system.

Classes.	Orders.
V. *Crustacea.* Articulated members; more than three pairs of feet; mostly two feelers (antennæ); eyes mostly compound; gills or respiratory vesicles.	1. Decapoda. 2. Stomapoda. 3. Amphipoda. 4. Læmodipoda. 5. Copepoda. 6. Isopoda. 7. Phyllopoda. 8. Lophopoda. 9. Parasita (Syphonostoma, Lernæida, Araneiformes).
VI. *Insecta* (*Insects*). Head separated from the thorax; articulated members; three pairs of feet; one pair of feelers (antennæ); eyes compound; pulmonary tubes; undergo certain metamorphoses.	1. Coleoptera. 2. Hemiptera (Heteroptera). 3. Orthoptera. 4. Neuroptera. 5. Lepidoptera. 6. Hymenoptera. 7. Diptera
VII. *Arachnida* (*Spiders*). Head united with the thorax; generally four pairs of limbs; simple eyes; no feelers; breathe through pulmonary sacs and air tubes; undergo no metamorphosis.	1. Pulmonaria. 2. Trachearia.
VIII. *Annelida* (*Worms*). Body mostly elongated, composed of a succession of annular segments; no articulated members; respiration by gills; generally red blood; aquatic (with few exceptions).	1. Dorsibranchiata. 2. Tubicola. 3. Terricola. 4. Suctoria.
IX. *Mollusca* (*Mollusks*). Body soft, with spongy, elastic, slimy skin, mostly loosely applied to the organs contained in it; complete vascular system; mostly enclosed in one or two calcareous shells.	1. Cephalopoda. 2. Pteropoda. 3. Heteropoda. 4. Gasteropoda. 5. Brachiopoda. 6. Conchifera. 7. Tunicata.
X. *Entozoa.* Bodies soft and transparent, greatly varying in shape and structure; no tentaculæ; live in other animals.	1. Sterilmintha. 2. Cœlelmintha. 3. Cystiformes.

Tabular View of the Animal Kingdom—*continued.*

Classes.	Orders.
(The following three classes—XI., XII., and XIII.—form the subdivision RADIATA, which is characterised by a regular disposition of similar parts around a common centre.)	
XI. *Echinodermata.* Body enclosed in a coriaceous or calcareous integument; intestinal tube attached to the inner walls of the shell by a fold of the lining membrane; marine animals; power of locomotion, though very limited in some of them.	1. Fistulida. 2. Echinida. 3. Asteroida *seu* Stellerida 4. Crinoidea.
XII. *Acalephæ.* Marine animals with gelatinous pellucid bodies; vessels; tentacula; traces of nerves; a certain degree of locomotive power.	1. Pulmonigrada. 2. Cilograda. 3. Physograda. 4. Cirrigrada. 5. Diphyda.
XIII. *Polypifera.* Body gelatinous or fleshy, mostly attached; consisting in some orders entirely of a simple digestive bag or sac; in some orders provided with a horny or stony skeleton; the mouth surrounded by a greater or less number of radiating tentacula; increasing by germs and buds.	1. Actiniæ, or Sea anemonies. 2. Lithophytes, or stony corals. 3. Keratophytes, or horny flexible corals. 4. Pennatulæ, or Sea-pens. 5. Hydræ.
XIV. *Infusoria. Polygastrica.* Body gelatinous, pellucid; numerous stomachs; mouth mostly fringed with cilia; no indication of nerves; microscopic animals; most of them move freely through their native element, but some attach themselves to a solid base.	1. Anentera, without an intestinal canal. 2. Enterodela, with an intestinal canal.

A.—VERTEBRATA.

100. The presence of an *internal* skeleton, composed of bone or cartilage, and forming a case or envelope to the nervous centres, constitutes the distinguishing characteristic of the animals belonging to this sub-kingdom.

The size and bulk also of the vertebrata mark the higher rank which they occupy in the scale of creation. The great number and variety of their organs require a larger space than is occupied by the bodies of most of the invertebrate animals. The smallest of the vertebrata still exceed an inch in length, and even the more minute of their organs may still be clearly discerned with the naked eye. They are greater in comparison to most of the animals of the invertebrate series. In *number* and *variety*, however, they are far surpassed by the latter group.

The affinities and relations in which the vertebrata stand to man are much more direct and infinitely more striking and important, than can be said with respect to any of the inferior orders of animals. The usefulness of the vertebrate animals to man in an infinite variety of ways, amply compensates for the injuries sometimes inflicted by some of them; moreover, their ravages are usually much more easily guarded against, than

are the depredations committed by the infinitely small animals of many of the lower orders.

The vertebrata are divided into four classes, viz., *mammalia*, *birds*, *reptiles*, and *fishes*.

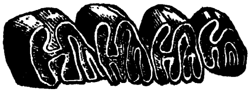
FIRST CLASS. MAMMALIA.

101. This class comprises the most highly developed of the vertebrata; they differ in many respects from the other three classes of vertebrate animals, but more particularly in this, that they bring forth their young alive, and nourish them during the earliest period of life. In the immense majority of them the body is covered with hair, which in some is agglutinated into prickles or bristles, and in some others into scales; in a few the skin is completely bare, or, at all events, shows only a few scattered hairs. The organs of the senses are highly developed in the mammalia; the immense majority of them are provided with an ear, though in some of them this is very small or even altogether rudimentary. The vertebral column is flexible in the mammalia, and the neck has, with few exceptions, seven vertebræ. There are four members; the number of toes varies, some having five, others four, or three, or two, or even a single toe. The trachea is provided with the epiglottis, as in man; however, the sounds omitted are by no means melodious, but mostly harsh, shrill, or hissing.

In the development of the organs of sense, of the brain, of the nervous system in general, and of the muscular system, the mammalia stand next to man, and so likewise, in regard to their intellectual powers. This class is, therefore, unquestionably of all the divisions of the animal kingdom, the one which interests us most. Besides that they supply to us an infinite variety of useful materials, in their flesh, fat, blood, hair, bones, skins, bowels, &c., many of them are from their comparatively high intellectual development, peculiarly adapted to assist man in many of his labors, and some of them even to become his companions and friends.

The subdivision of the mammalia into orders rests principally upon the differences which the animals exhibit in the conformation of their limbs, and of their apparatus of mastication.

In reference to their position in the mouth we distinguish between *front* teeth and *back* teeth; the front teeth are the *incisors* and the *canine* teeth;



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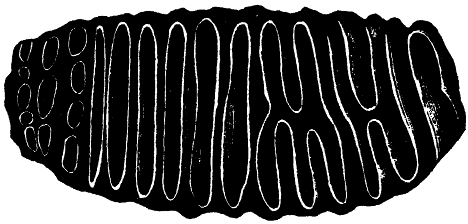


15.

the back teeth are called *molar* teeth. The two pairs of the latter, which are situated more in front, adjoining the canine teeth, are usually termed *pseudo-*

molars, or small grinders; these latter are altogether absent in many animals. The teeth differ in structure; thus, the front teeth are completely covered with enamel, whereas in many of the mammalia, in the ruminantia, for instance, the summits of the back teeth are not so covered, but present simply crescent-like ridges of enamel (see fig. 14), as that substance is worked in with the other constituent materials of the teeth, which consist of alternating plates of *enamel*, *ivory*, and *cementum*, or bony substance. In some other animals, in the elephant, for instance, the molar teeth are formed of alternate vertical plates of enamel, bone, and *crusta petrosa*, arranged transversely to the jaw; the summits of these teeth present the appearance illustrated in fig. 15. In many animals the molar teeth have rounded or tuberculated summits, in others they are raised into sharp points and edges. The former is the case in the human species, the latter in the canidæ and felidæ.

The limbs present great differences of conformation, according to the different purposes which they are intended to serve in the several classes of animals, (prehension, running, leaping, digging or burrowing, swimming). The fore-legs often differ very considerably from the hind-legs. The *foot* of the animal is called *hand*, when it is so constructed that one of the fingers is *opposed* to the rest; in the contrary case, it is called *paw*. The points of the fingers or toes are either covered with flat or curved *nails*, or they terminate in sharp curved *claws*, or finally, they are enclosed in a hard *hoof*.

The immense majority of mammalia are terrestrial animals. Some orders of the mammalia live exclusively on plants, and bring forth young, covered with hair, and endowed with sight at their birth, but which continue to suck for a long time; others feed on flesh alone, and bring forth young, naked and blind at their birth, but which suck only a short time; a third group, finally, live both on animal and vegetable substances.

Classification of the Mammalia.

A. Fore and Hind Legs fully developed.			B. Fore and Hind Legs imperfectly developed.	
Separate Fingers terminated by distinct Nails or Claws.		Fingers more or less consolidated, and enclosed at their extremity in a hard hoof.		
With Incisors, Canines, and Molars.	Deficient in one or several of the Three kinds of Teeth.	With Strongly developed Molar Teeth.	Teeth like the Carnivora.	Mostly conical Teeth of simple structure, or Baleen Plates.
1. Bimana. 2. Quadrumana. 3. Cheiroptera. 4. Carnivora. 5. Marsupialia.	6. Rodentia. 7. Edentata.	8. Multungula, or Pachydermata. 9. Solidungula. 10. Ruminantia.	11. Phocidæ s. Pinnipedia.	12. Cetacea.

First Order. Bimana.

102. This order is constituted by the human species only (*Homo sapiens*). In the general structure of his body, man may be said to resemble the other mammalia; and indeed, as we have already stated, the human body gives us the standard of comparison for the bodies of all other animals; but his reason and the gift of speech elevate man immensely above the rest of the animal kingdom, and constitute him its sovereign ruler. Among the distinguishing characteristics of man, and which widely separate him even from those animals that otherwise approach him nearest in structure and organisation, we may mention here also more particularly his erect attitude, the bareness of his skin, the greater flatness of his nails, the equality in the length of all his teeth, and the close ranging together of them in both jaws; and last, though not least, the peculiar conformation of his hands, and the restriction of their number to *two*, whereas the monkey tribe have *four*.

Notwithstanding the strongly-marked distinctions presented by individuals of different zones and climates, we look upon all the different races of man simply as varieties of one and the same species which have arisen in course of time, and under the influence of peculiar circumstances.

The human species is usually divided into five races, viz.:—

1. The *Caucasian race:* fair complexion; soft hair of all shades, from auburn or light brown to jet black; small, oval face; arched brow. This

[Caucasian.]

[Mongolian.]

race, which we consider the noblest and most perfect, includes all Europeans, the inhabitants of Western Asia, of North Africa, and of the regions of the North Pole.

2. The *Mongolian race:* complexion yellow or tawny; thin, straight, black hair; flat, broad face, with prominent cheek-bones; nose small and flat; small-set eyes. To this race belong the inhabitants of Central Asia, the Kalmuks, Kirgises, Mongols, Chinese, &c.

[African or Negro]

3. The *African* or *Negro race:* sable skin of darker or lighter hue; woolly, crisp, black hair; small head, with prominent jaws, and receding forehead and chin; flat nose; thick lips, and projecting muzzle. To this race belong the inhabitants of the greater part of the African continent.

4. The *American race:* clay-colored skin, or coppery complexion; low forehead; prominent cheek-bones; sleek, black hair. This race comprises the aborigines of America.

5. The *Malay race:* brown complexion; curly black hair; flat nose; forehead somewhat prominent. To this race belong the Malays proper, and the aborigines of the South Sea islands.

Second Order. Quadrumana.

103. Of all animals, the *Quadrumana* approach nearest to man in form and organisation. They have all three kinds of teeth, and the eyes directed forwards; but their most distinguishing characteristic is the opposable thumb on both pairs of extremities, which converts their four feet into *hands*, giving to all four equally the power of prehension. On the other hand, the erect attitude is not natural to them as it is to man, since, from the absence of the arch, which constitutes the sole in the latter, they cannot stand firmly on their posterior limbs. The Quadrumana inhabit only the warmer regions of the earth. They live socially together among the woods —with the exception, however, of the *baboons*, which live for the most part among rocks and mountains—mostly in trees, which they climb with amazing agility. Many of them (the *Monkey* tribe) avail themselves of their long and powerful tail in climbing and in leaping from tree to tree, often suspending themselves by twisting this muscular organ around the branches. They live principally on fruit, but in confinement they speedily begin to relish animal food, more particularly eggs and pastry. Many of them prey also on insects. Although the conformation of their body, and their great muscular power, would seem to fit them for many useful labors, yet only a few of them—viz., the *Ape* tribe, and even these only when young—can be rendered any way serviceable to man. The *monkey* and *baboon* tribes are characterised by cunning, petulance, caprice, and a most mischievous disposition; the baboons more particularly show an amount of sullen ferocity, coupled with a comparative absence of intelligence, which renders them nearly altogether untameable. The Quadrumana present an extraordinary variety of species, many of which are but imperfectly known. But the whole order would seem to be most properly subdivided into three families, viz.,

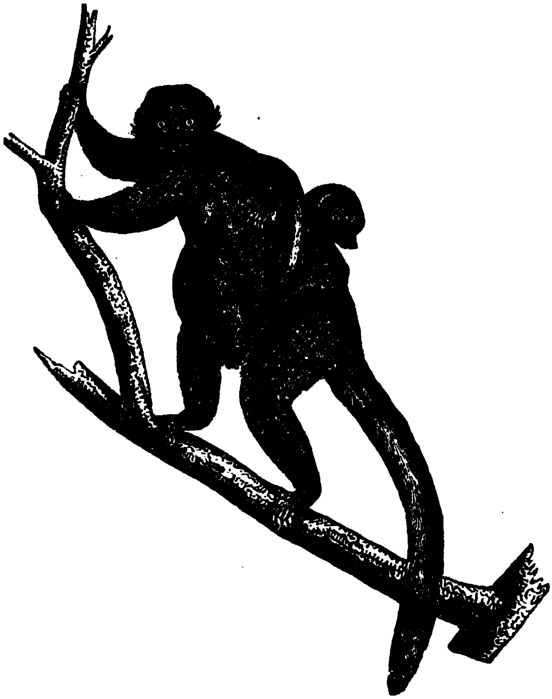
1. the *Simiadæ*, which includes the apes, monkeys, and baboons of the Old World; 2. the *Cebidæ*, or monkeys of the New World, marked by partial or complete absence of the thumb upon the hands, the presence of an additional molar tooth in either side of each jaw, and a long tail, which serves them as an additional organ of prehension; and, 3. the *Lemurs* (Lemuridæ), which have thumbs on both pairs of extremities, while the teeth are less regular both in form and number than in the other two families. Some of the order Simiadæ bear a close resemblance to the human form and face; we may mention the *orang-outang* (Simia satyrus), a native of Borneo and Sumatra, which reaches a height of from six to seven feet; and the *Chimpanzee* (Simia troglodytes), (fig. 16), which grows somewhat above four feet high; these apes have no caudal appendage. They have given occasion to many fabulous stories of wild men of the woods. The Javanese assert even that they can speak, but that they conceal this faculty lest they should be made to work by man. To this family belong also the long-armed apes, *gibbons* (Hylobates lar), and the caudate species; for example, the *Douc*, or Cochin-China monkey (Semnopithecus nemæus), which is remarkable for the singular variety of its colors; the *green monkey* (Cercopithecus sabæus); and the *long-tailed monkey*. Of the genus *Papio*, which belongs also to the Simiadæ, we may mention the *Magot* (Papio inuus), which is commonly known as the Barbary or showman's ape. This is remarkable as being the only one of the quadrumana which is at present a regular inhabitant of Europe (on the rock of Gibraltar). Of the genus *Cynocephalus*, or dog-headed baboon, we may mention here the *Gray baboon* (Cynocephalus hamadryas), and the *mandrill* (C. maimon), with its strangely painted head.

16.

The most obvious character which distinguishes the *Cebidæ*, or monkeys of the New World, from the *Simiadæ*, is the *lateral* or *outward* direction of the apertures of their nostrils, which in the Simiadæ are directed downwards or forwards. In some of them the tail is not only an organ of prehension, but also of touch, the end of it being destitute of hair, and furnished with a sensitive skin; this is the case more especially with the *spider monkeys* (Ateles), and the *howling monkeys* (Myceti). In the genus *Cebus*, which comprises the monkeys known as *Sapajous*, *Sajous*, and *Capucins*, the tail is covered with fur to its extremity, which deprives it of its delicacy as an organ of touch. Of the other genera of the Cebidæ, we may mention the Sagoin, or *squirrel monkey* (Callithrix sciurea), the Douroucouli, of nocturnal habits and with cat-like movements, and the *ouistiti*, or *marmozet* (Hapale).

The *Lemuridæ* are confined to the Old World; they associate in troops, and live on fruits and insects; the habits of most of them are nocturnal, for which they are adapted by the large size of their eyes. Fig. 17 represents

the *white-fronted lemur*. We may mention here besides, the *loris* or *slow lemurs;* the *otolicnus* or *galago*, which has large membranous ears like the



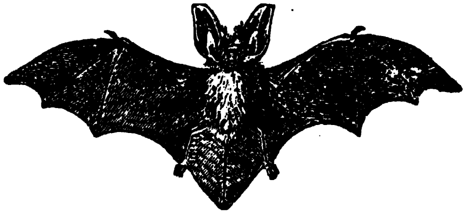
17.

bat; and the *galeopithecus* or *flying lemur*, remarkable for an extension of the skin between the anterior and posterior limbs on each side, and also between the two posterior limbs, including the tail.

THIRD ORDER. CHEIROPTERA (*the Bat Tribe*).

104. These animals bear considerable resemblance to the *muridæ* or mouse family, from which they are, however, widely distinguished by a thin *naked* membrane, continued from the skin of the body, and spread over a species of umbrella framework, constituted by the lengthened bones of the anterior members, and more especially of the fingers. This membranous expansion is attached also to the hind limbs, which assist in keeping it extended; it gives the animal the power of *flight*. Concealed during the day in the hollows of trees, the crevices of masonry, and the chinks or fissures of rocks, the animals of this tribe come forth at twilight from their hiding-places, in search of their insect prey, which they secure with remarkable dexterity. Some species, found only in hot countries, subsist on the blood of other animals; and a few of them live on fruit. The most remarkable families of

the bat tribe are—the RHINOLOPHIDÆ (*nose-leaf bats*), of which the best known are the *greater* and *lesser horse-shoe bats*, so called from the peculiar form of the front of the nose-leaf; and the *Megaderms* of Africa and the Indian Archipelago, which are remarkable for their enormous nose-leaf and very large pair of ears;—the PHYLLOSTOMIDÆ are also characterised by a nose-leaf, but of less complicated structure than the RHINOLOPHIDÆ. They are for the most part inhabitants of South America; to this family belongs the genus *Desmodus*, which includes the *True Vampyres;* though the name *Vampyre* is usually attached to another species, of which the *vampyrus spectrum* is the most distinguished representative. It is of these animals that so many marvellous stories have been related;—the VESPERTILIONIDÆ, among which we mention the *flitter-mouse*, or *common bat* (Vespertilio pipistrellus); the *Plecotus auritus*, or *long-eared bat* (fig. 18), the *Vespertilio murinus*, or *mouse-colored bat;* the *Noctule*, or *red bat* (Vespertilio noctula).



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The bats of the *frugivorous* section are inhabitants of the East Indies, Africa, and Australia. One of the most remarkable species of this section is the *Java Roussette* (Pteropus Javanicus), a bat with a fox-like head, and an enormous expanse of wings (no less than five feet). The largest of the Pteropidæ is the *black roussette* ((Pteropus edulus), which is of the size of a small dog; its flesh is eatable.

FOURTH ORDER. CARNIVORA (*the Carnivorous Tribe*).

105. A large group of animals which prey upon the rest of the animal world. They are to this end provided with claws, and a powerful dental apparatus. The order is divided into three suborders, distinguished by the nature of their food, and the corresponding organisation of their dental apparatus; viz., the *insectivora*, with their teeth raised into conical and pointed tubercles; the *carnivora proper*, with sharp, cutting, molar teeth; and the *herbi-carnivora*, which subsist on a mixed animal and vegetable diet, and are accordingly provided with tuberculated molars.

The *insectivora* apply the sole of the foot to the ground; in size and in their mode of life, most of them resemble the Rodentia. Among the animals belonging to this suborder, we mention the *hedgehog* (Erinaceus), characterised by its prickly skin, in which it rolls itself up into a compact round ball; it remains rolled up in its retreat during the day, sallying forth at twilight in search of insects, slugs, frogs, toads, mice, snakes, &c.; the common *shrew* (Sorex araneus), and the *pigmy shrew* (S. pygmæus), the smallest of all quadrupeds. They both dwell in burrows; the body of the shrew exhales a faint musky odor, which makes these animals distasteful to cats. The *common mole* (Talpa europæa), is characterised by its broad, hand-shaped fore-paws, provided with powerful claws, and by which it is enabled not only to dig through the soil, and cut through the roots or other obstacles opposing its progress, but

also to throw backwards the earth removed at each stroke. It feeds on larvæ and earth-worms. The small mounds of earth thrown up by this useful little animal, and which are so well known as mole-hills, prove sometimes annoying, more especially on meadows; but they do little harm if they are at once levelled again with the ground.

The eyes of the mole are so small and so little developed, that their very presence was formerly called in question. The *blind mole* of the Cape (Talpa cœca) is completely blind. The *Chrysochloris*, or *Talpa inaurata* of the Cape, is remarkable for the metallic lustre of its fur. In the *Condylura*, of North America, the termination of the nostrils is surrounded by moveable cartilaginous points that radiate like a star when expanded.

The true *carnivora* are characterised by the nature of their teeth, which are formed for seizing, cutting, and tearing animal flesh. The dental apparatus consists of six incisor teeth in each jaw; the canines, which in the greater number of them are large, strong, and pointed; the molar teeth, which are usually from four to seven in number, and are of three different kinds, viz., *false molars*, which immediately follow the canines, and are more or less pointed; the large *carnivorous tooth*, which follows the false molars, and is especially adapted for tearing animal flesh, by the form of its summit, which is raised into a cutting edge; and the *tuberculated molars*, which are the last or hindermost.

The carnivora are divided into several families differing in their structure and in their mode of life.

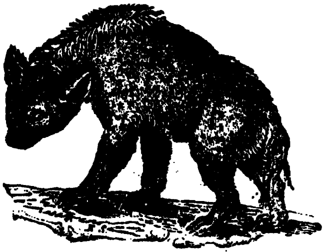
The animals of the *Ursine* family are plantigrade in their walk; the *tuberculated* molars predominate in them, and the *carnivorous* tooth is of much less size and sharpness than in the animals of the *cat* tribe. They have short, massive limbs, and a heavy gait; the larger and more northern species live almost exclusively on animal food; the smaller species, of warmer regions, subsist almost entirely on vegetable food, though generally they do not disdain smaller animals, eggs, &c. None of the animals belonging to the *Ursidæ* can be said to be of any great utility to man. The typical genus of the family is the *Ursus*, or *Bear*. The animals of this genus are completely plantigrade in their walk, and can rear themselves on their hind-legs; among them we mention: the *white polar bear* (Ursus maritimus), which lives amidst the snow and ice of the arctic regions, and feeds on seals and fish; the *black bear*, or *American black bear* (Ursus Americanus); the *brown bear* (Ursus arctos), which used in former times to be publicly exhibited by bear-leaders. This animal passes the winter in caves, earth holes, or hollow trees, in a state bordering on torpidity. The *raccoon* (Ursus lotor) has the singular custom to dip its food in water before tasting it. Among the smaller species of the family we mention the *coati* or *nasua*, and the *ailurus* or *panda*, an inhabitant of the Himalayan ridge.

The animals of the family *Mustelidæ*, or *vermiform carnivora*, are characterised by the shortness of their legs, and the elongation, slenderness, and flexibility of their bodies. Though of comparatively small size, they are as sanguinary in their propensities and habits as even the largest of the carnivora. Among the members of this family we mention: the *badger* (Meles), which digs for itself a deep and well-formed domicile in the ground, from which it sallies forth at night in search of its food, which consists of roots, earth-nuts, fruits,

and eggs, and also small mammals; the *glutton* (Gulo) of the northern regions of the Old and New World, which is erroneously supposed to be an enormous feeder; the *skunk* (Mephitis), which inhabits the West Indies and Java, and is remarkable for the intolerable odor of the secretion from its glandular pouches. The following supply us with some of the most beautiful furs: the *pole-cat* (Mustela putorius); the *ferret* (Mustela furo), which is employed to hunt rabbits; the *ermine* (Mustela erminea); the common *weasel* (Mustela vulgaris); the common *marten* (Mustela martes); the *sable* (Mustela zibellina); and the *otter* (Lutrum), an aquatic animal, with naked soles, and webbed and spreading toes.

Of the *Viverridæ*, we mention: the *ichneumon* of Egypt (Herpestes ichneumon), a most useful animal, which serves more especially to restrain the multiplication of the crocodile, by devouring its eggs, and also the young crocodiles newly hatched; it destroys also small reptiles, rats, mice, &c.; and the *civet* or *viverra* (Viverra zibetha), which yields *civet*, a perfume of a powerful musky odor.

Among the *Canidæ*, or *dog tribe*, we mention the *fox* (Canis vulpes), renowned for its cunning; the *arctic fox* (Canis lagopus); the *jackal* (Canis aureus); the voracious *wolf* (Canis lupus), long extinct in this country, but still found on the Continent, and more particularly in the northern parts of Europe, and also in northern Asia; and the domestic *dog* (Canis familiaris), of which there are an extraordinary number of varieties or breeds. The *dog* is remarkable for its sagacity and reasoning powers. Some of the breeds are trained to hunt, or to point or set at game; others to guard the flocks, or to watch premises, &c. The dogs of St. Ber-



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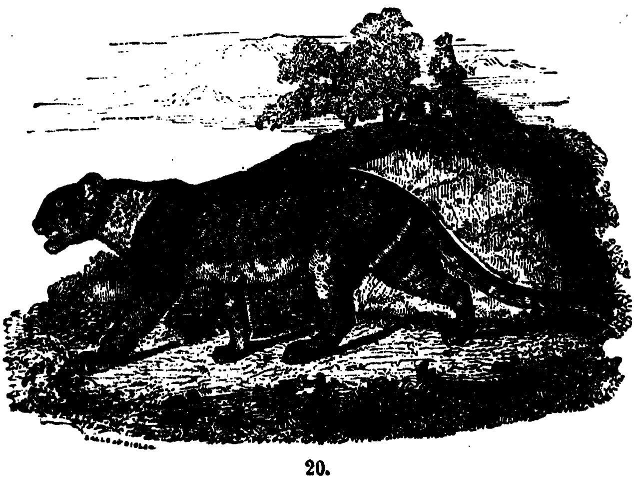


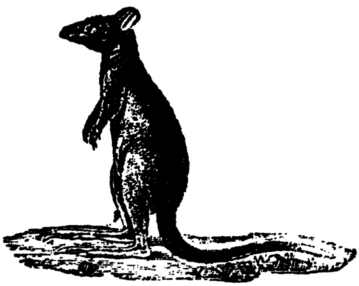
20.

nard, which are trained to rescue unfortunate travellers lost in snow-drifts, afford an admirable instance of canine sagacity and gentleness.

The *hyena* (fig. 19), which preys on carrion, and even digs up dead bodies from the grave, forms the connecting link between the *dog* tribe, or *Canidæ*, and the *cat* tribe, or *Felidæ*. To the latter belongs the king of animals, the *lion* (*Felis leo*), which is restricted to the interior wilds of Africa, and to some parts of Asia. The *tiger* (Felis tigris), a still more formidable animal than the lion, is confined to Asia. The *panther* (Felis pardus), fig. 20; the *leopard* (F. leopardus); the *ocelot* (F. pardalis); and the *jaguar* (F. onca), the most dangerous of the American felines, are remarkable for their beautiful spotted skins. The *American lion*, or *puma*, is only an indifferent representative of the royal lion of Africa and Asia. The *domestic cat* was formerly erroneously supposed to be a descendant of the *wild cat* (Felis catus.) The *lynx* (Felis lynx) has the ears tufted with pencils of hairs.

Fifth Order. Marsupialia.

106. The animals of this order belong exclusively to the tropical regions of America, to the Sunda Islands, and New Holland; most of them attain the size of rats or hares, some reach a larger size. Most of these animals have a pouch at the lower part of the abdomen, in which they carry their young about with them for several weeks. The young are born in a very undeveloped state. In many of the animals which we are going to enumerate here, the pouch is almost entirely wanting, being indicated only by a slight fold of skin; but the general conformation of the osseous frame, and more particularly of the pelvis, shows them to belong to the order Marsupialia. Some of these animals subsist on vegetable food, others resemble in their habits and mode of life the martin and the weazel. To the former belong the *phascolarctos* or *koala*, which carries its young, when it has left the pouch, on its back for some time; the *great kangaroo* (Halmaturus) (fig. 21), which attains the size of a roe, is the largest animal of New Holland; the *kangaroo-hare* and the *kangaroo-rat*.



21.

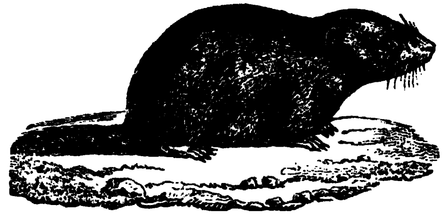
The carnivorous marsupialia produce several young at a time, and some of them carry their young on the back. We notice the following: the *dasyurus* or *ursine opossum;* the *opossum* or *didelphis*, which is restricted to America, where it proves a great nuisance to farm-houses, by destroying poultry and other domestic birds. The female opposum bears its young fifty days in its pouch, and afterwards some time on the back. The *Virginian opossum* (Didelphis marsupialis) attains the size of a rabbit. The *petaurus* or *flying phalanger*, has the skin of the body extended between the anterior and posterior limbs on each side for some distance beyond the flanks; forming a kind of sustaining parachute, which aids the animal in its long leaps.

SIXTH ORDER. RODENTIA (*Gnawers*).

107. This order is subdivided into several families, such as the *Sciuridæ*, *Muridæ*, &c.

The animals belonging to the *Sciuridæ* or *squirrel tribe*, are most of them graceful and agile, and live principally amongst trees, and in hollows of trees, a few only burrowing amongst the roots. Their food consists chiefly of nuts, acorns, &c., or fruit, and in the spring, of buds and young shoots. We notice the *climbing rat* (Isodon), the *marmot* or *mountain rat* (Arctomys), the *dormouse* (Sciurus glis), the *squirrel* (Sciurus vulgaris), the *pteromys* or *flying squirrel* (Sciurus volitans).

The animals of the family *Muridæ* are all of them of small size; most of them live under ground in burrows, whence they issue forth at night in search of their food, which consists principally of grains and roots, but also of animal substances. Their fecundity is astonishing. The young are born blind. Among the animals belonging to this family we notice the *black rat*, or *old English rat;* the *brown rat*, which is commonly known as the *Norway rat*, though it has really no claim whatever to that title; the *pouched rat* (Mus bursarius); the *common mouse* (M. musculus); the beautiful little *harvest mouse;* the *long-tailed field mouse;* the *hamster* (Mus cricetus), which gathers immense stores of grain. To the family *Arvicolæ* or *Voles*, which is distinguished from the *Muridæ* by a peculiarity in the teeth, indicating an affinity with the *Castoridæ*, belong the *short-tailed field mouse* (fig. 22); the *water-rat* (M. amphibius); and the *lemming*, or *migratory rat*, of Northern Russia and Siberia (Mus decumanus).



The *jerboa* or *dipus* forms an intermediate link between the squirrels and the rats; this animal is distinguished by the enormous development of its hind-legs and tail, which enables it to take prodigious leaps. It bears, in this respect, considerable resemblance to the *Macropodidæ* (long-footed), or kangaroo tribe.

The family *Chinchillidæ* consists of a number of small South American rodents, highly valued on account of their fur; of these we mention the *chinchilla* (Chinchilla lanigera), which may be considered the type of the family.

Of the *Leporidæ*, or *hare tribe*, renowned for their fine-flavored flesh and beautiful fur, we notice the *rabbit* (Lepus caniculus) and the *hare* (Lepus timidus).

The most important animal of the *castoridæ*, or *beaver tribe*, is the *beaver* (Castor fiber), which may be regarded as the type of the family. This animal differs from all other rodentia by its horizontally-flattened, nearly oval-shaped, scaly tail, and webbed hind-feet. It dwells on the banks of rivers, where, if not molested by man, it constructs its remarkable habitation in the shape of a baker's oven, and with an entrance under water; if molested by man, it takes to burrowing. The beaver is pursued for its fur, which

being peculiarly adapted for felting, is extensively used in the manufacture of hats; and also for a peculiar odoriferous secretion, termed castor, which was formerly much used in medicine, but is now chiefly employed by perfumers. It has nearly disappeared from Europe, but abounds still in the northern parts of Asia and America, though even there its ranks have been considerably thinned by the injudicious exterminating pursuit that has been carried on against them.

The *porcupine* (Histrix cristata), a burrowing, solitary, nocturnal animal, which is met with in the south of Italy, in Sicily, Spain, and Barbary, forms the type of the *Hystricidæ* or *Aculeata*, or *porcupine tribe.*

To the *Cavidæ*, or *Guinea-pig tribe*, belong the *cavy* (Cavia); the *Guinea-pig*, or *cobaya*, which was introduced into Europe shortly after the discovery of South America, and has now become quite naturalised; the *agouti*, which in the length of its hind-legs resembles the *Leporidæ;* and the *capybara* or *hydrochœrus*, which is of the size of a small pig.

Seventh Order. Edentata.

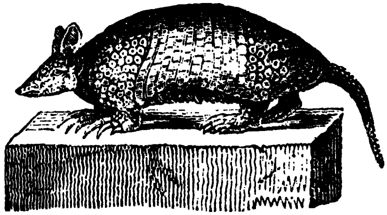
108. The animals belonging to this order are characterised by the absence of teeth in the front of the jaws, and the imperfect development of the molars, which are destitute of enamel and of distinct roots. A small section of the group (the ant-eaters and pangolins) are altogether *toothless.* Their toes, which approach the *ungulated* structure, are armed with sharp claws. The *true edentata* are characterised by the *total* absence of teeth, and by their long, slender, and extensible tongue, which is moistened by a viscid secretion which enables the animal to secure its insect prey. Of this family there are two genera, viz., the *great ant-eater* (Myrmecophaga), and the *manis* or *pangolin.*

The family *tardigrada*, which belongs to this order, contains only a single genus, viz., the *bradypus* or *sloth*, an animal which has been most erroneously looked upon by naturalists as one of nature's most imperfect creatures, the

23.

truth being, that this animal is most admirably adapted for the mode of life it is intended for by nature, viz., *under* the branches of trees. Placed upon the ground, indeed, the sloth is a slow-moving and most awkward-looking animal, but in a tree it moves with great ease and rapidity. There are only two species of sloth known, viz., the *ai*, or three-toed sloth, of which there are two varieties; and the *unau*, or two-toed sloth.

The *water mole*, or *duck-billed platypus* (Ornithorhyncus paradoxus), (see fig. 23,) and the *echidna*, or *porcupine ant-eater*, constitute a distinct sub-order of the *Edentata* (or more correctly of the subclass of *Ovo-viviparous mammalia*, which is constituted by this order and the Marsupialia). This order is termed *Monotremata*, from the circumstance that the oviducts, the urinary duct, and the intestines, terminate all of them in a common canal or *cloaca*, in which peculiar conformation of the reproductive apparatus these animals show a near approach to the class of birds. The Ornithorhyncus is exclusively confined to New Holland and Van Diemen's Land, the Echidna to Australia, Van Diemen's Land, and the islands of Bass's Straits.



24.

To the family *loricata* (scaly animals), of the same order, belong the *armadillo* (see fig. 24), and the *pichiciago* (Chlamyphorus truncatus), characterised by the scaly integument of their bodies.

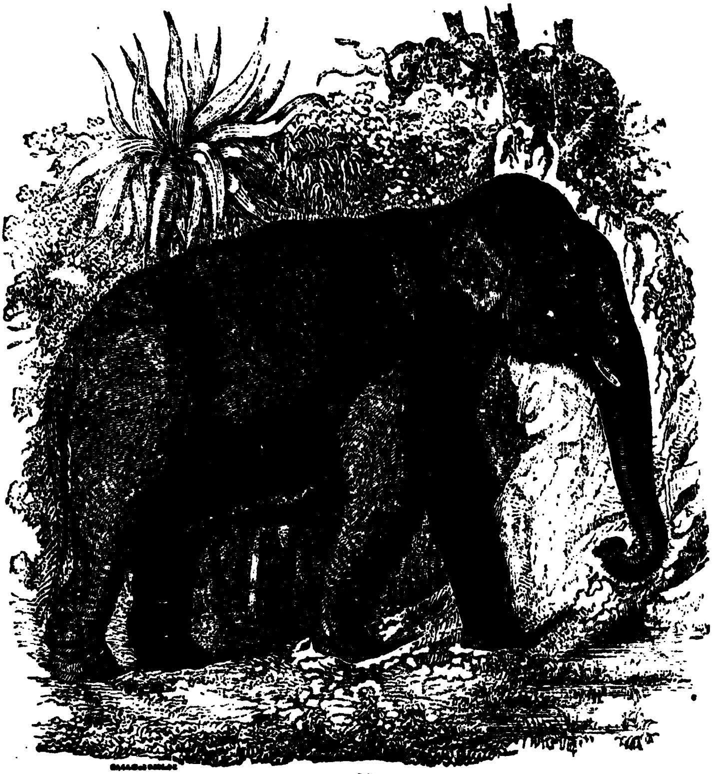
EIGHTH ORDER. PACHYDERMATA* *seu* MULTUNGULA.

109. This order derives its name from the thickness of the hide which characterises the animals constituting it. In most of them this thick integument is only thinly and partially covered with hair. The Pachydermata have from two to three toes, enclosed in a firm horny skin. They subsist principally upon vegetable substances. In this order we find the largest terrestrial animals, which are confined exclusively to the Old World.

The *Proboscidean* group of this order contains but one family, the *elephantidæ*, or *elephant tribe*, which consists of a simple genus, the *elephant*, (Elephas), (fig. 25, which represents an elephant of the East Indies.) Of this genus there are two varieties, the *Asiatic* and the *African*, of which the former is larger and more docile than the latter, which differs from it, moreover, by its larger ears and longer tusks, and by its arched forehead. With a colossal bulk and vast strength, the elephant combines an extraordinary degree of intelligence and docility; the heaviness and ungainliness of its movements are amply compensated by the possession of that wonderful organ, the *trunk* or *proboscis*, which is adapted to serve a great variety of purposes. In fig. 15 we have given a representation of one of the compound molars of the elephant; much more important than these are the enormous tusks, weighing from two to three hundred pounds each and more, the *ordinary* weight of the pair being between four and five hundredweight.

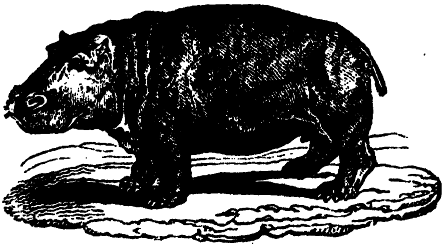
* Naturalists are generally agreed now to class the *Solidungula*, or *horse tribe*, and the so-called *Herbivorous Cetacea* (the *dugong* and *manatee* tribe), with the Pachydermata; but, for the sake of convenience, we will here still retain the old classification.

These tusks supply that valuable material, *ivory*. The animals of the elephant tribe live socially together in the humid forests of Asia and Africa, and are quiet and inoffensive as long as no provocation is offered them.



25.

The most unwieldy of all terrestrial animals is unquestionably the *river horse*, or *hippopotamus* (fig. 26), which is generally classed with the family *Suidæ*, or *pig tribe*, forming, as it were, the connecting link between the hog and the elephant on the one, and the hog and the herbivorous cetacea on the other side. This animal is now exclusively confined to the rivers and lakes of Africa. Among the other animals belonging to the pig tribe, we mention the *common hog* (Sus-scrofa), one of the most valu-



26.

able animals, and which has been imported also into the New World, where it now abounds; the *babyroussa* of Java and the Molucca Islands, which is remarkable chiefly for the extraordinary curvation of the tusks of the upper jaw; the *peccary*, or *South American boar*, whose flesh has a disagreeable odor, imparted to it by a glandular secretion.

Of the *Tapiridæ*, or *tapir tribe*, we notice the *tapir* (Tapirus), possessed of a flexible proboscis, which is endowed with a certain degree of prehensile power; and the *rhinoceros*, with its bullet-proof hide, and the solid curved and pointed horn which it bears on the nasal arch,—in some species of rhinoceros there are two horns, the one situated behind the other.

Ninth Order. Solidungula (*Single-hoofed Pachydermus*).

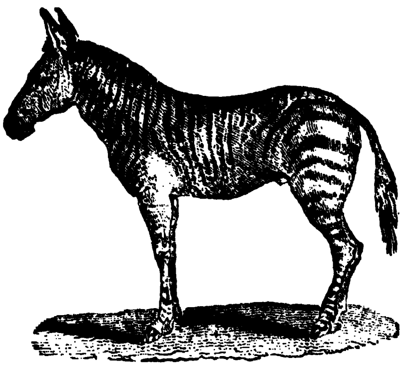
110. This order consists of a single family, the *Equidæ*, or *horse tribe*, at the head of which stands the *horse* (Equus caballus), an animal equally distinguished for gracefulness, fleetness, and docility, and which is certainly one of the most important and useful to man. The horse is spread over the whole earth. The wild horses of Tartary are almost to a certainty descendants of domesticated races, and so are the wild horses of the pampas of South America, into which part of the world the horse was first introduced after the conquest of the South American continent by the Spaniards. There are numerous breeds or varieties of horses. The *mule* is a hybrid between the ass and the mare; another similar hybrid is produced also between the horse and the she-ass.

The dental apparatus of the horse consists of six incisors in each jaw, with six molars above and below on either side, and in the males, also two small canines in the upper jaw, and sometimes in both jaws; the females lack the canine teeth. The complete and perfect dental apparatus of a male of this family stands accordingly as follows:—

Molars.	Canines.	Incisors.	Canines.	Molars.
$\frac{6}{6}$	$\frac{1}{1}$	$\frac{6}{6}$	$\frac{1}{1}$	$\frac{6}{6}$

The incisors present a dark brown depression on their cutting edge, which wears off with increasing age, and affords thus a means of judging of the age of the animal.

We notice here also the *zebra* (Equus zebra), (fig. 27,) a native of Southern Africa; the *quagga* (Equus quagga); the *wild ass*, or *onager* (Equus asinus), which abounds in the wild plains of Tartary, and to which the domesticated stock is generally referred.



Tenth Order. Ruminantia (*Cud-chewing animals*).

111. This order embraces the most useful of the mammalia. The animals belonging to it supply us with leather, wool, horn, flesh, milk, butter, cheese, and tallow. Many of them are, moreover, most valuable beasts of burthen and draught, slow-paced indeed, but enduring. Almost all of them have become domesticated, and a great many breeds or varieties have been produced. The ruminant animals are all characterised by the cloven or divided hoof, and by the absence of incisor teeth from the upper jaw; with few exceptions they are provided with two horns. They are all herbivorous, and their alimentary apparatus or stomach is separated into four divisions. The first and largest is called the *paunch*, into which the half-chewed fodder or herbage is first received; from this the food is conveyed to the second stomach, called the *honeycomb*, where it is formed into balls, and whence it is carried again to the mouth to undergo the process of further mastication. When this has been accomplished, the food passes into the third chamber of the complex stomach, called the *manyplies*, which has its mucous-lining membrane disposed in large longitudinal folds, so as to form deep *lamellæ*, like the leaves of a book; the food is then finally received into the fourth and last stomach, called the *reed*, where it mixes with the gastric juice, and is digested.

The ruminant animals form several large families, among which we notice the *Camelidæ*, or *camel tribe*. The animals of this tribe have no horns, but are provided with callous cushions on the breast and knees. We distinguish the *Arabian*, or *one-humped camel* or *dromedary* (Camelus dromedarius), and the *Bactrian*, or *two-humped camel* (C. bactrianus), with two humps or bunches on the back; the former is employed chiefly in Arabia, North Africa, Syria, Persia, the latter in Central Asia. By its great strength, its gentle disposition, and its patient endurance of hunger, thirst, and fatigue, the camel is eminently adapted for traversing the barren expanse of the desert and arid plains of Asia and Africa, and it is not inaptly indeed that it has been termed "the ship of the desert." The camel affords also sustenance to its possessor by its milk and flesh, and the hair is employed in the manufacture of cloth.

The American camels, or *llamas*, are smaller than the camels of the Old World, and have no humps. There are three species of them, viz., the *guanaco*, the *vicugna*, and the *little lama* or *paco*, or *alpaca*. These three species, but more especially the two latter, yield a very fine wool, almost of silky texture.

The most remarkable of all the members of this family, and indeed of the whole animal kingdom, is the *giraffe* (Camelopardus, fig. 28), standing eighteen feet high to the crown of the head, which is surmounted by four radiating bony protuberances covered with hairy skin. There are two varieties known of this fleet quadruped—one of them peculiar to Nubia, Abyssinia, and the adjacent countries, the other a native of Southern Africa.

An extensive section of the ruminant animals, viz., the *cervidæ* or *deer tribe*, is characterised by the possession of bony, deciduous* horns, termed

* *Deciduous*, falling off annually.

antlers. Among the animals belonging to this family we notice the *hart* (Cervus), the *roe* (C. capreolus), the *noble hart*, stag, or red deer (C. elaphus), the *fallow-deer* (C. dama), the *rein-deer* (C. tarandus), and the *elk* (C. alces).

28.

The *Muschidæ*, or *musk deer tribe*, so called from the circumstance that the strong perfume *musk* is obtained from one of the species which constitute the tribe, viz., from the *true musk deer* (Moschus moschiferus), are inhabitants of the Altaic range, near Lake Baikal, and also of Nepaul, Thibet, and the districts adjacent to the North of India and to China. The musk tribe is characterised more particularly by the absence of horns.

Another large division of the order Ruminantia is composed of animals with persistent hollow horns (*Cavicornia*, or *hollow-horned animals*). In some families of this division, as in the *antelope tribe*, the horns are composed of a solid bony cone, covered with a horny sheath; in others, as in the

sheep and *goat tribe*, the cone is more or less hollowed into cavities and cells. Of the latter tribe, we notice the *moufflon* of Corsica and Sardinia; the *domestic sheep* (Ovis aries); the Egyptian or Syrian *fat-tailed sheep* (O. steatopyga); the *Caucasian* and the *Jemlah ibex;* the *Syrian goat*, the *Angora goat*, and the *Cashmir goat* of Thibet, all three, but more especially the last, renowned for the fine wool which they supply,—from the wool of the Thibet breed are woven the celebrated Cashmir shawls; the *domestic goat* (Capra hircus).

Among the animals of the *antelope tribe*, we notice the *true antelopes*, which are remarkable for their fleetness and the graceful symmetry of their bodies; to this section belong the *spring-bok* of Southern Africa, and the swift *gazelle* (Antelope dorcas); the *bush antelopes*, to which section belongs the so-called *bush goat*, which is found in Sierra Leone; the *capriform antelopes*, to which section belongs the *chamois goat* of the Alps, Pyrenees, and other mountain ranges of Europe; and the *bovine antelopes*, among which we mention the *nyl-ghau* of India, the *addax* of Africa, and the *gnu* of Southern Africa.

One of the most important families of the order Ruminantia is formed by the animals of the *ox* tribe (Bovidæ), which from times immemorial have been most useful to man. The most conspicuous members of this family are, the *ox* (Bos taurus); the *zebu*, or *Brahmin ox*, distinguished by the large fatty hump which it carries on its back; the *common buffalo* (Bos bubalus); the *Cape buffalo* (Bos caffer); the *Indian buffalo;* the *musk ox* (Bos moschatus); the *aurochs*, or *European bison* (Bos urus), which inhabits the forests of Lithuania; and the *American bison*, which is commonly but erroneously called the *buffalo.*

ELEVENTH ORDER. PHOCIDÆ *seu* PINNIPEDA (*the Seal tribe*).

112. This order and the next may be said to form the connecting links between the mammalia and the fishes. The body is elongated and conical, tapering from the chest to the tail; it is covered with short, glossy hair, set closely against the skin; the limbs are converted into oars or paddles: the arm and forearm of the anterior pair, and the thigh and leg of the hind-limbs, are so short, that little more than the fore-paw and the foot advance from the body. These limbs are admirably adapted for swimming, but on land they hardly enable the animal to crawl along. The Phocidæ are inhabitants of the sea; however, from time to time they visit the shore; they subsist on fishes and shell-fish. The skins, the fat, and the tusks of several species of them, form articles of commerce.

29.

We notice the *common seal* (Phoca vitulina, fig. 29); the *elephant seal* of the South Seas; the *gray seal;* the *Greenland* or *Harp seal;* the *sea lion*

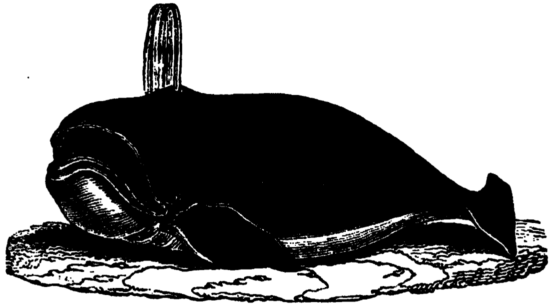
(Otaria jubata, Phoca jubata), the *crested seal* (Phoca cristata), the *sea monk* (Phoca monachus).

The *walrus*, *morse*, or *sea cow* (Trichecus rosmarus) attains a length of from eighteen to twenty feet, and a weight of from fifteen hundred to two thousand pounds. This animal is characterised principally by the enormous development of the canine teeth of the upper jaw, which reach a length of from eighteen to twenty-four inches, and are stout and solid. These tusks serve various purposes; the animal uses them with great effect in defending itself from the attacks of the Polar bear; also as an instrument of progression in climbing up floating icebergs and the sides of rocks; and also to tear up the long wreaths of sea-weed, which constitute a great part of its food.

TWELFTH ORDER. CETACEA (*the Whale tribe*).

113. This order embraces the largest animals in existence. In external form and shape, the animals of the whale tribe bear the strongest possible resemblance to fishes. The posterior members are altogether absent and the anterior extremities are still more exclusively adapted for propulsion in the water, than is the case in the seal tribe. The Cetacea are absolutely confined to the sea. The skin of these animals is bare, showing scarce a trace of hair on the upper lip. The oil, whalebone, and spermaceti which they supply, are valuable articles of commerce.

The Cetacea breathe through nostrils, situated at nearly the highest point of the head; they eject also water through the nostrils. They inhabit principally the Arctic seas. We notice the *Balæna*, or *Greenland Whale* (fig. 30), which attains a length of from sixty to eighty feet, and a weight of from fifty to sixty tons; the *Rorqual* or *Balænoptera*. These two constitute the family *Balænidæ*, or *Whalebone Whales*. They have no teeth; the palate is furnished instead with an apparatus for straining out the small mollusks and fishes, and the medusæ on which these huge animals subsist. This consists of a series of plates of *baleen* or *whalebone*, suspended from the roof of the mouth, with their edges forming a sort of loose fringe, composed of matted fibres, which reaches a length of from six to ten, or even twelve, feet. The *spermaceti whale*, or *Cachalot* (Physeter macrocephalus), of the family *Catodontidæ*, is found sometimes above a hundred feet long. This animal yields spermaceti and ambergris.



30.

Of the *Delphinidæ*, *or dolphin tribe*, we notice the *narwhal* (Monodon), and the *dolphin* (Delphinus). The dolphins are remarkable for the celerity of their movements, and are very voracious. The whales, cachalots, and

dolphins feed upon polypi, fishes, mollusks, and medusæ. The *herbivorou cetacea*, such as the *dugong* or *halicore* of the Indian seas, and the *manatee* or *lamantin* of America and Africa, are now usually classed by naturalists with the pachydermata.

SECOND CLASS. BIRDS (AVES).

114. The most distinguishing characteristics of the animals of this class are the feathers, which cover the skin. The anterior members have the form of wings; the jaws are bill-shaped and toothless; the tongue in most birds is hard. Birds have two nasal and two auricular apertures, the latter lacking the outer ear. Their long neck, composed of from nine to twenty-three vertebræ, greatly facilitates the movements of the head; the comparatively large size of the brain accounts for the tenacious memory and the remarkable intelligence and docility of many birds. The respiratory apparatus is highly developed in birds, the respiration being carried on not in the lungs alone, but in the whole interior of the body. This peculiar respiratory organisation imparts considerable lightness to the bodies of birds and, in conjunction with the light and hollow structure of their bones enables these animals not only to support themselves in the thin medium wherein they are destined to move, but to skim through it with greater or less velocity. Birds are the most tuneful of all animals, in fact, they alone possess the true gift of song. The temperature of the blood in birds ranges between 100° and 120° Fahrenheit, which is higher than is found in the mammiferous animals.

The propagation of the feathered tribe is effected by *eggs*, which are incrusted with a calcareous shell, and are generally laid to the number of from six to twelve, rarely so many as twenty and more. The maturation of the young enclosed within this shell, requires an incubation of generally three weeks' duration. The young, after they have burst from the shell, are tended, fed, and protected by the parents with truly solicitous care.

The nutriment of birds consists of every species of vegetable and animal matter. Some birds dwell on the land, others on the water, and many of them alternately on both. Birds permanently resident in a country are called *resident birds*, as the sparrow, for instance; some are *birds of passage* as the thrush, or *migratory birds*, as the swallow.

The characters upon which the division of birds into orders, families, and genera is based, are furnished principally by the conformation of the beak and feet. Some have feet adapted for swimming, some for walking, some for running, some for hopping, some for climbing. The thigh bone is short and straight, and in most birds nearly concealed from view as far down as the articulation of the knee. A single bone, which forms the continuation of the leg, represents the tarsus and metatarsus, and bears at its lower end the toes, which never exceed the number of four. The conformation of the beak or bill also varies considerably, that organ being long and pointed in some birds, short and thick in others; conical, cylindrical, laterally compressed or horizontally depressed, straight, curved, or simply hooked at the end. In many birds the bill is surrounded at its base by a yellow membrane, called the *cereous* membrane.

The animals of the feathered tribe are eminently useful to man by thei

flesh, eggs, and feathers. Many of them delight us, moreover, by the elegance and symmetry of their forms, their gay and brilliant plumage, their graceful evolutions, and above all, the exquisite melody of their song. The injury they occasion is very small in proportion to the advantages which they yield. It is rare indeed that even the largest and most rapacious of them become formidable to man, and no bird is poisonous.

Birds may be divided into two principal groups. The first group is composed of birds which are hatched blind and naked, require to be fed for a considerable time in the nest, and subsequently live on one sort of food. They hop on the ground, and their flight is rapid and easy; they pass the greater part of their time on the wing. The birds of the second grand division are hatched with open eyes, and with a flocculous or downy covering; and they no sooner leave the egg, than they run about and pick up their food, which is of the most varied kind. They walk or run on the ground, but rarely fly; the most of them are land birds, but some are aquatic.

115. Division of Birds.

A. Leg feathered to the spur, or nearly so.	B. Lower part of the leg only feathered.
1. Raptores, or birds of prey.—With powerful legs and toes, furnished with sharp-pointed hooked talons; powerful upper mandible bent at the end, and terminating in a sharp point; cereous membrane.	4. Cursores, or runners.—Legs and feet adapted for rapid motion; wings imperfect, and unsuitable for flight.
2. Insessores, or perching birds.*—Toes adapted for hopping or climbing; claws mostly compressed. Bill usually without the cirement.	5. Grallatores, or waders.—Legs very long, adapted for wading; toes partially or slightly united by a fold, or quite free; rarely webbed; wings powerful.
3. Rasores, or gallinaceous birds.—Toes partially united by a small fold, or quite distinct. Claws not compressed, mostly blunt; upper mandible mostly arched; sometimes with a cirement.	6. Natatores, or swimmers.—Legs moderately long; toes usually connected, forming a swimming-paddle; in some the hind toe is not included in the web.

* This order includes also the *Scansores*, or climbing birds.

First Order. Raptores (*Birds of Prey*).

116. Powerful feet and claws, a sharp sight, and considerable swiftness and vigor of flight, render these birds peculiarly adapted for preying upon other birds and animals; though many of them feed also on carrion. The indigestible portions of their food, such as wool and feathers, are ejected again by the mouth in the shape of pellets. The female birds are generally larger than the males; they build their nests, which are constructed without much art, in lofty situations, such as the ledges of rocks, the tops of high trees, &c. They generally lay only a limited number of eggs, (two or three, and rarely more than four).

31.

Some of the birds of this order are diurnal, and are distinguished by their dense plumage, and by the lateral direction of their eyes; such are the families of the vultures and falcons.

In the *vultures*, (Vulturidæ), the head, neck, and tail are bare of feathers. These birds live socially together; they feed on carrion, and are very ravenous. As interesting examples of the group, we mention the *tawny vulture* (fig. 31); the *condor* of the Andes, the largest of all flying birds, the expanse of whose wings is usually nine feet, but reaches sometimes ten and even eleven feet; the *Egyptian vulture*, commonly called *Pharaoh's Chicken;* the *gray vulture*, (Vultur cinereus). Between eagles and vultures, naturalists place the *lammergeier* or *bearded griffin* of the Alps (Gypaëtos barbatus, fig. 32).

32.

The *falcons* (Falconidæ) constitute a numerous family, distinguished by symmetry of form, and great boldness and daring. They prey chiefly on living animals, from mammals down to insects. The largest birds of this tribe are the eagles, of which the most remarkable are the *golden eagle* (Falco fulvus); the *erne* or *great sea eagle* (F. albicella), and the *osprey*, or *fish-hawk;* the latter two are expert fishers. Of the smaller birds of the falcon tribe, viz., the true falcons, several of which were formerly held in very high estimation for their use in the sport of falconry, the following are the most remarkable, viz., the *Gyr*, *Jer*, or *Iceland falcon* (F. islandicus), the *merlin* (F. æsalon), the *kestrel*, the *hawk*, or *goshawk* (F. palumbarius), the *sparrow-hawk* (F. nisus); also the *kite* (F. milvus), the *swallow-tailed kite* (F. furcatus), and the *buzzard* (F. buteo). The *secretary bird* (Gypogeranus secretarius), a native of South Africa, distinguished by the extraordinary length of its tarsi, in which it resembles the waders, and by the plumes at the back of its head, which led the Dutch to bestow the name Secretary upon it, is a most useful bird in the localities which it inhabits, as it destroys vast numbers of snakes and other poisonous reptiles.

The *nocturnal birds of prey*, constituting the family *Strigidæ*, or the *Owl* tribe, are distinguished from the *diurnal* birds of prey chiefly by their loose plumage, and the anterior direction of their very large eyes; from the large size of the pupils of the eyes so much light is admitted, that the bird is quite dazzled if he opens his eyes in full day; it is, therefore, almost exclusively restricted to hunt its prey by night, or in the twilight. Owls are most useful birds, as they destroy vast numbers of mice and other vermin. When the owl happens to appear abroad during the day-time, it is followed about by flocks of little birds; it is on this account sometimes employed by fowlers as a decoy bird. The best known of this tribe are the *eagle-owl* (Strix

bubo), the *long-eared owl* (S. otus), the *barn owl*, and the *screech-owl* (S. noctua).

SECOND ORDER. INSESSORES.

117. The number of individuals included in this order is so immensely large, that it has been found necessary to subdivide them into several sub-orders. They have weak legs. In the true insessorial birds, the toes are three before and one behind; but in the *Scansores*, or *climbers*, which we include here in the order *Insessores*, two of the toes are directed backwards. We find in this order the most melodious songsters, and also many birds distinguished by the elegance and beauty of their plumage, by the swiftness and gracefulness of their flight, by their docility, and by the architectural skill which they exhibit in the construction of their nests.

Many of the birds of this order constitute almost by themselves distinct tribes; this is the case, for instance, with the *gaping-billed goat-sucker* (Caprimulgo), and the *swift* (Cypselus). Others form part of large families.

The *singing birds* (Canores) compose an entire sub order, to which belong more particularly the following: the *swallows* (Hirundinidæ); of these may be mentioned here the *chimney swallow*, the *martin*, or *house swallow*, the *bank swallow or sand-martin*, and the *esculent swallow* (H. esculenta), which is found in the Indian Archipelago, and whose nests are so much valued by the Chinese as delicacies for the table;—the *flycatchers* (Muscicapidæ);—the *Shrikes* or *Butcher birds* (Laniadæ), of which many have the curious habit of impaling the animals they have caught upon a large thorn: they are rapacious birds, and will even attack smaller birds of their own tribe. In the family of the *thrushes* (Merulidæ *seu* Turdidæ), we meet with the beautiful golden *oriole* (Oriolus galbula), the *missel-thrush* (Turdus viscivorus), the *field-fare* (T. pilaris), the *song-thrush* (T. musicus), the *blackbird* (T. merula), and the *mocking bird* (T. polyglotta). Some of the above named are liked for the delicacy of their flesh, others for their vocal performances; in the latter they are, however, infinitely surpassed by the *songsters* or *warblers* proper (Sylviadæ), mostly small and sober-colored birds. The *nightingale* (Sylvia luscinia) is celebrated above all birds for the compass, variety, and melody of its notes; the following also contribute their share to the animation and charm of our woods, groves, and hedges, viz., the *common white-throat* (S. cinerea), the *black cap* (S. atrocapilla), the *redstart* (S. erithacus), the *red-breast* (S. rubecula), and the *reed-warbler* (S. arundinacia). The smallest of our native birds belong also to this tribe, viz., the *golden-crested wren* and the *common wren* (S. regulus and S. troglodytes).

To this group belong also the *Accentors* or *Dunnocks*, the *Wagtails*, and the lively *Titmice*, among which latter we may mention the *great titmouse* (Parus major), the *blue titmouse* (P. cœruleus), the *penduline tit* (P. pendulinus), which is celebrated for its ingeniously-constructed nest suspended over water, usually among reeds. The *nuthatches* bear considerable resemblance to the *tits*. Among the *Ampelidœ* or *Chatterers*, we mention the beautiful *Bohemian chatterer*, or *black-throated waxwing*.

The *crow* tribe (Corvidæ), are distinguished by their strong bill, and loud, shrill, or croaking voice; they mostly live on fruit or kernels, but also on worms, grubs, flesh, &c. To these belong the *jay* (Corvus glandarius), the

magpie (C. pica), the *chough* or *jackdaw* (C. monedula), the *hooded crow* (C. cornix), the *seed crow* or *rook* (C. frugilegus), the *common* or *carrion crow* (C. corone), and the *raven* (C. corax), which latter occasionally attacks small animals. All these are characterised by their sombre plumage, and by their superior intelligence. They may be taught to speak with great distinctness. The latter faculty is possessed also by the *starlings* (Sturnidæ), which are very serviceable to quadrupeds, by relieving them from the insects that infest them. The *bird of paradise* (fig. 33), which is confined to New Guinea and the neigbouring islands, is highly prized for its beautiful long feathers.

The granivorous warblers feed their young with insects; some species of them congregating in flocks, do occasionally considerable damage in newly-sown fields; others are caught in large numbers for the table. We may mention here the *field*, or *sky-lark* (Alauda arvensis), the *crested lark*, the *heath lark*, the *golden hammer* or *yellow bunting* (Emberiza citrinella), the *snow bunting* (E. nivalis), and the delicious *ortolan* (E. hortulana). The *finches* (Fringillidæ), are among the most common of our birds, particularly the *chaffinch* (Fringilla cœlebs), the *gold-finch* or *thistle-finch* (F. carduelis), the *haw-finch*, the *gray linnet* (F. cannabina), the *siskin* (F. spinus), and the *canary bird* (F. canaria). All these birds are easily kept in confinement, and are prized for the melody of their song; which is not the case, however, with the *sparrow* (F. domestica), whose plumage, moreover, is more sober and modest than its character. To the *Fringillidæ* belong also, the *bullfinch*, the *pinefinch*, and the *crossbill* (Loxia curvirostra).

In the suborder *tenuirostres* are found the smallest of all birds; viz., the *humming birds* (Trochilidæ, fig. 34), which are entirely restricted to America, where they abound most between the tropics, not usually extending far on either side. The humming birds are remarkable also for the glorious hues and the brilliant metallic lustre of their plumage. They live chiefly on small insects.

To the *tenuirostres* belong also the Upupidæ, or *Hoopoes*, among which we mention the *European Hoopoe*, which is characterised by its beautiful crest, the length and slenderness of its bill, and the shortness of its feet.

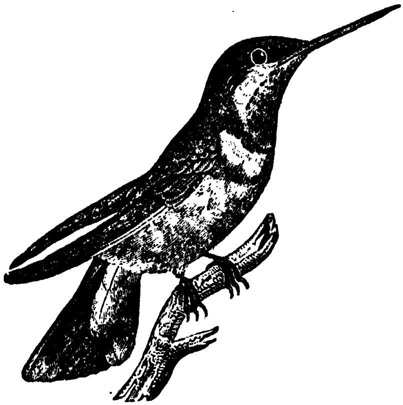
The *Buceridæ*, or *hornbills*, are remarkable for the very large size of the beak, and also for an extraordinary protuberance which is generally found to surmount the latter in the grown bird.

The *Alcedinidæ*, or *kingfishers*, have long quadrangular bills; the front toes are united in them at the base, for which reason the name *Syndactyli* has also been given to them.

The *Meropidæ*, or *bee-eaters*, prey with impunity upon bees and wasps.

In the *climbers*, or *scansores*, two of the toes are directed forwards, and two backwards. To this family belong the *cuckoo* (Cuculus canorus), which builds no nest, but drops its eggs singly into the nests of small singing birds,

which hatch the egg thus surreptitiously introduced among their own, and feed the intruder at the expense of their own natural offspring; the *indicator* or *honey-guide* of Africa, which guides the natives to the nests of the wild bees by flitting before them, and reiterating a peculiar cry; the *toucans* or



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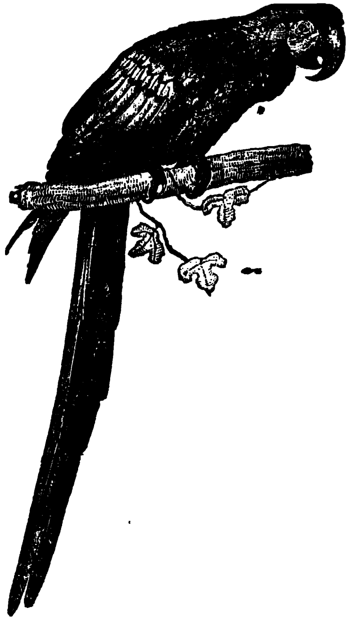


35.

Rhamphastidæ, with their enormous bills; and the *woodpeckers*, which search the trunk and branches of trees for insects and larvæ, making first an aperture with their strong wedge-shaped bill, and then withdrawing their prey by means of their extensible tongue, which is barbed towards the tip, and moistened with a glutinous saliva. To this latter group belong the *black woodpecker* (Picus martius), the *green woodpecker* or popinjay (P. viridis), the *spotted woodpecker* (P. varius), and the *wryneck* (Junx torquilla).

The great family of the *parrots*, or *Psittacidæ*, brings up the rear of this extensive order. The Psittacidæ are characterised by their short hard beaks, which are generally high arched, and invested at the base with the cereous membrane; they have a thick fleshy tongue, and may be taught to imitate the sound of the human voice in speaking and singing, although their voice is naturally harsh and unmusical. They are natives of tropical and the warmest temperate regions, and feed chiefly on fruits, seeds, honey, &c., rarely on insects or flesh. There are about 200 species of the true parrot tribe, all remarkable for the splendor of their plumage and the drollness of their gestures; among these we may mention the *common gray parrot* (Psittacus erithacus), the *cockatoo* (Ps. cristatus), the *blue maccaw* (Ps. ararauna), and the *red maccaw* (Ps. macao, fig. 35), the *parrakeets*, the *love-birds*, and the *lories*.

THIRD ORDER. RASORES, OR SCRATCHERS (GALLINACEÆ).

118. The gallinaceous birds have a short, usually slightly arched beak, and strong feet, peculiarly adapted for scratching. Their powers of flight are inconsiderable; they have a disagreeable shrill voice, but are highly esteemed for their delicate flesh and eggs. The young are hatched with their eyes open, and are generally able to walk about in search of food as soon as they leave the shell. The cock birds are larger and of gayer and more brilliant plumage than the hens.

Among the pigeon tribe (Columbidæ), of which all the members associate invariably in pairs, and feed their helpless young for a considerable period, we notice the *ringdove* (C. palumbus), the *stock-dove* (C. œnas), the *turtle-dove* (C. turtur), the *laughing*, or *Indian turtle-dove* (C. risoria), and the *passenger pigeon* (C. migratoria), which is occasionally seen in immense flocks in Central and North America; and finally the *crowned pigeon* (C. coronata).

Under the section of grouse (Tetraonidæ), we note the *capercailzie* (Tetrao urogallus), the *black grouse* (T. tetrix), and the *hazel grouse* (T. bonasia). Nearly allied to the *grouse* are the *ptarmigans* (T. lagopus), natives of the southern parts of the temperate zone, among which we mention the *gray ptarmigan* or *Alpine partridge*, which changes its plumage in winter to snow-white.

Among the pheasant tribe (Phasianidæ), which originally came from Asia, and are in general distinguished by the gorgeousness of their plumage, we find the *peacock* (Pavo), our *domestic cock* (Phasianus gallus), the *common pheasant* (Ph. colchicus), the *gold* and *silver pheasants* (Ph. pictus and nycthemerus), the *argus pheasant* (Argus), the *guinea hen* (Meleagris Numida), and the *turkey* of North America (Meleagris gallopavo). To this section of the order *Rasores* belong also the *partridges* and *quails*.

The *mœnura*, or *lyre-tail* of Australia, so called from the curious conformation of the plumage of its tail, is also placed by many naturalists among the gallinaceous birds, though it belongs, perhaps, more properly to the order *Insessores*.

FOURTH ORDER. CURSORES, OR RUNNERS.

119. This order includes the largest birds. From the imperfect development of their wings, and the character of the plumage, they lack the power of flight. The strong and highly developed legs and feet, on the other hand, render these birds most powerful runners, and qualify them for outstripping the fleetest horse. The cursores are excessively voracious, devouring all sorts of vegetable and animal food. This order contains only a small number of species, viz., the *Apteryx* of New Zealand, the *cassowary* (Casuarius indicus, fig. 36), and the *African*, or *two-toed ostrich* (Struthio camelus, fig. 37), the tallest of all birds at present known to exist; this gigantic bird attains a height of from 6 to 8 feet; it furnishes the well-known ostrich feathers. It inhabits the sandy deserts of Arabia and Africa. In the torrid zones it leaves its eggs to be hatched by the heat of the sun, but in temperate climates it attends to their incubation. In South America we find the *three-toed*, or *American ostrich*, or *rhea*, and in New Holland the *emu* (Rhea Nova Hollandiæ).

This order includes also two species of huge birds which are now extinct, viz., the *dodo* of the Mauritius, Bourbon, and some neighbouring islands, and the *dinornis* of New Zealand.

36.

37.

FIFTH ORDER. GRALLATORES, or WADERS (more correctly *Stilt-walkers*).

120. The birds of this order connect the rasores and cursores with the natatores. The length of their legs, and the absence of feathers at the lower part of the tibia enables them to wade into water of a certain depth, and thus to procure fish, mollusks, aquatic worms and insects, &c., which constitute their food. Their toes are in general slightly webbed. When flying, they stretch out their long legs behind, using them as a rudder.

Among the *Otidæ*, or *bustard* family, we mention the *great bustard*, the largest of all the native birds of Europe; this noble bird was once common in our island, but has now almost altogether disappeared from it, being only occasionally met with still in the western part of Norfolk.

Among the family of the herons (*Ardelidæ*), we note the *common heron* (Ardea cinerea), the *white heron* (A. ægretta), which furnishes the feathers for the well-known beautiful heron-plumes; the *bittern* (A. stellaris), and the *spoonbill* (Platalea), remarkable for the unusual spoon-shaped form of its beak. Of the genus *stork* we notice—in addition to our ancient and well-known friend, the *common stork* (Ciconia)—the *Argala*, or *adjutant stork* of India (fig. 38), from which, and from an allied species in Senegal, the beautiful Marabou feathers are obtained; both the Indian and Senegal species devour multitudes of noxious animals, and remove a vast amount of carrion. The *great ibis* (Tantalus ibis, fig. 39), and the *sacred ibis* (Ibis religiosa), are African birds; the latter was worshipped by the ancient Egyptians, and even

embalmed after death, probably because its appearance announced the rise of the Nile. The *flamingo* (Phœnicopterus), remarkable for the extra-

38.

39.

ordinary length of its legs and neck, and for its rosy plumage and carmine wings, connects the *waders* with the *Anatidæ*, or *duck tribe*, one of the families constituting the order *natatores.* Among the *Gruidæ*, we mention the *crane* (Grus).

The birds of the *plover tribe* (Charadriadæ) frequent open sandy shores, and exposed commons or moors; to this tribe belong the *golden plover* (Charadrius pluvialis), the *lapwing* or *peewit* (Vanellus cristatus), the *turnstone* (Strepsilas collaris), the *oyster-catcher* (Hæmatopus ostralegus), and the *red-shank* (H. rufipes).

The members of the *snipe* tribe (Scolopacidæ) feed on insects, worms, slugs, aquatic mollusks, &c., which they usually obtain by thrusting their long, flexible, and sensitive bills into the mud or moist soil. Among them, we mention the *common snipe* (Scolopax media), the *green-shanks* and *sandpipers*, the *woodcock* (Scolopax rusticola), the *ruff* and the *curlew.* Nearly allied to this family are the *stilts*, or *stilt plovers*, and the *avocet*, which latter bird is remarkable for a bill of extraordinary length and slenderness, and which curves upwards towards the tip.

The *Rails* (Rallidæ) approximate in many points very closely to the natatores. Among them we notice the *water-rail* (Rallus aquaticus); the *moor-hens* or *Gallinules;* the *land-rail* or *crake* (Gallinula grex); the *green-legged moor-hen* (G. chloropus); the beautiful *purple-rail* (Porphyrio); the *black water-coot* (Fulica atra), common in ponds and lakes; and the *screamers*, which are remarkable for the sharp hard spurs with which the wings are armed at the shoulder joint.

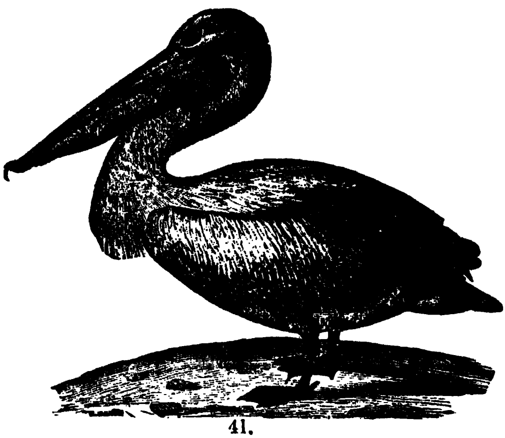
Sixth Order. Natatores, or Swimmers, or Web-footed Birds.

121. These birds have short legs, and *palmated* or *webbed* feet, the toes being connected together by a membrane. The plumage is dense, and there is generally an undergarment of down, which is especially thick beneath the body. They live mostly upon or in the water, and resort to the shore chiefly for the purpose of building their nests and rearing their young. Most of them live principally upon fish and mollusks, which imparts to their flesh a rank fishy flavor. The order includes five families, viz., the *Colymbidæ*, or *divers;* the *Alcidæ*, or *Auks;* the *Pelicanidæ*, or *pelicans;* the *Laridæ*, or *gulls;* and the *Anatidæ*, or *ducks.*


40.

Among the *divers* we mention the *crested diver* (Colymbus cristatus), the *great northern diver* (Colymbus glacialis), and *the red-throated diver* (Colymbus septentrionalis). Among the *auks* of the Northern Ocean, the *great* or *northern auk*, or *Arctic penguin* (Alca impennis), the *guillemot*, and the *puffins.*

In the southern hemisphere, these birds are represented by the *penguins*, a most remarkable group of birds, with very short legs, placed so far back that the body is quite upright when the bird is standing on the ground; the wings are covered with short, rigid, scale-like feathers, and lack accordingly altogether the power of raising the body in the air. The *Patagonian penguin* is a most valuable bird to the inhabitants of Patagonia and Van Diemen's Land, on account of its dense downy plumage, and the copious amount of fat or oil which it yields.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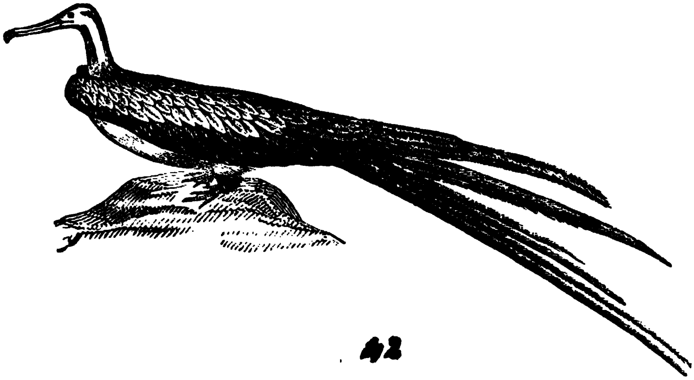
Among the *pelicans*, which are remarkable for the extent and power of their wings, we notice the *pelican* (Pelicanus onocrotalus, fig. 41), with its enormous pouch, and hooked-tipped bill; the *cormorant*, the *gannet* or *solan goose*, the *frigate* or *man-of-war bird* (Tachypetes, fig. 42), the *tropic bird*, and the *darters.*

The *gulls* and *petrels* are generally distinguished for great powers of flight; their wings are long and pointed. Among the *true gulls* we notice the *terns*, or *sea-swallows*, the *glaucous gull* (Larus glaucus), the *silver* or *herring gull*

(Larus argentatus), the *skuas* or *robber-gulls*, and the *storm-finch* or *black-backed gull*; among the *petrels*, the *fulmar* of the Arctic seas, *St. Peter's fowl*, and the gigantic *albatross*.



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The most serviceable of the aquatic birds are the members of the *duck* tribe, for their eggs, flesh, and feathers. Among them we notice our *domestic goose* (Anser cinereus), the *swan* (Cygnus olor), and the many species of *ducks*, as the *wild duck* or *mallard*, the *sheldrake*, the *Muscovy duck*, the *teal*, the *eider duck* (Anas mollissima), the *scoters*, the *pochard*, the *mergansers* or *gooseanders*, &c.

THIRD CLASS. REPTILES (AMPHIBIA, OR LURKERS).

122. Some of the animals of this class have the skin completely naked, but in the greater number the skin is covered by a thick epidermic layer of scales, or of horny or bony plates. The nasal fossæ, through which the animal draws in air, and which open into the throat, are but little developed. In some reptiles, gills exist in the early period of life, which afterwards usually wither and disappear; some, however, retain these organs during life. The auditory apparatus is much less complete than in the first or even in the second class of animals; the external ear is almost always entirely wanting.

The blood of reptiles has the same temperature as the surrounding medium. Their muscular system is highly developed, and they are consequently capable of great muscular exertion. They are possessed also of the reproductive faculty, that is, the faculty of reproducing parts that have been accidentally lost. The reptiles are almost as mute as fishes, for, with the exception of the serpent's hiss and the croaking of frogs, this class lacks the power of sound.

Reptiles differ greatly in the external conformation of their frame. Some have four feet, some two, and some, as the serpents, are altogether without these locomotive appendages. With few exceptions reptiles increase by eggs; however, they never produce such an enormous progeny as the fishes do.

The number of genera is small, amounting on the whole to only 1270. Most members of the reptile class cast their skin periodically, and some

undergo changes of shape or color, assimilating in some measure to the transformations of insects. The impression which the animals of this class create is almost universally a repulsive one, which may be attributed in a measure to their solitary lurking habits, and to the insidious manner in which they usually approach their victims. Moreover, several of the members of this class are venomous, which is the case with no other class of animals. In some of them the body is rendered repulsive from its absolute nakedness. Their want of sociableness, their indifference for their young, their lack of mechanical instinct, and their general uselessness, contribute also to explain and warrant the dislike so generally entertained of them.

123. Division of the Reptiles.

A. Heart composed of two auricles opening into a single ventricle;* undergo no change; skin covered with scales or plates; no metamorphosis.		B. Skin naked; gills; undergo transformations.	
1. Chelonia—Turtles.	2. Sauria—Lizards.	3. Ophidia—Snakes.	4. Batrachia—Frogs.
Four feet; ribs immoveably connected together; Sternum broad; mouth destitute of teeth.	Four feet (rarely two or none); moveable ribs; lower jaw united by sutures.	Destitute of feet; no eyelids; ribs moveable; no sternum; lower jaw united by cartilage.	Four feet (rarely two or none); ribs short, or wanting.

First Order. Chelonia, or Tortoises.

124. In the *tortoise* tribe the dorsal vertebræ, ribs, and sternum, form two great shields, of which the upper is called the *carapace*, the lower, the *plastron*, and which are united together on each side, forming a species of cuirass, with openings for the passage of the head, feet, and tail, and covered with horny plates, or with a coriaceous skin.

The tortoises are the most useful animals of all the reptile class, their flesh and eggs being most excellent and nutritious food. In certain places where they are not liable to much disturbance, they are occasionally found in very considerable numbers.

The shell of many of them, called tortoise-shell, is manufactured into many useful and ornamental articles. Of this tribe the following deserve to be noticed: the *land tortoise* (Testudo græca), the *geometrical tortoise* (T. geometrica), the *snuff-box tortoise* (Cistudo), the *marsh tortoises* (Emys) of the Orinoco, which come in great shoals to the so-called Tortosa Islands, to lay their eggs, of which millions are collected, and used to make oil; the *European marsh tortoise* (E. Europæa), the rapacious and gluttonous *river tortoises* (Aspidonectes), with coriaceous shields; the *marine tortoises*, among

* In crocodiles, however, the heart is formed almost in the same manner as in birds and mammalia, presenting two distinct ventricles and two auricles.

which we note the *green turtle* (Chelone midas), which occasionally measures 6 or 7 feet in length, and weighs from 500 to 800 pounds; this is the species most valued as food. The best *tortoise-shell* is obtained from the *hawk's-bill turtle* (Chelone imbricata).

SECOND ORDER. SAURIA (*the Lizard Tribe*).

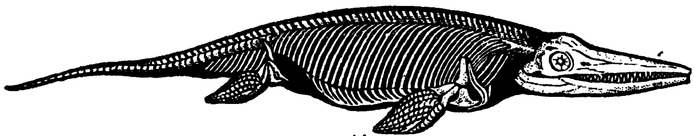
125. Of the three sections into which this order is subdivided, we notice first the *armed lizards* (Loricati), whose bodies are covered with bony shields. The *crocodile* (Crocodilus), and other equally dangerous aquatic reptiles, which in internal structure bear a close resemblance to the mammiferous quadrupeds, belong to this section.

The best known of these is the *crocodile* of the Nile (C. vulgaris, fig. 43),

43.

which attains a length of from 20 to 30 feet; the *gavial*, or *crocodile* of the Ganges (C. gangeticus), is distinguished from this chiefly by the extreme prolongation and narrowness of the muzzle. The American crocodile is called the *alligator*, or *cayman* (C. lucius), and is distinguished by the shortness and roundness of the muzzle.

Among the petrified remains of similar animals we meet with the *ichthyosaurus*, fig. 44, and *plesiosaurus*, fig. 45, gigantic animals with paddle-



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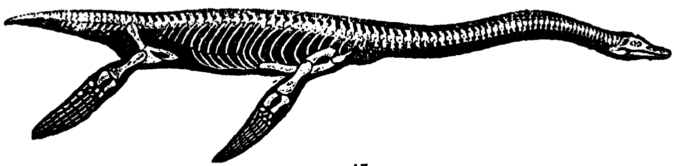
feet, and which attained the enormous length of from 10 to 17 yards. The Plesiosaurus had no less than 90 vertebræ.

The section of the scaly saurians (*Squammati*), embraces the family of the



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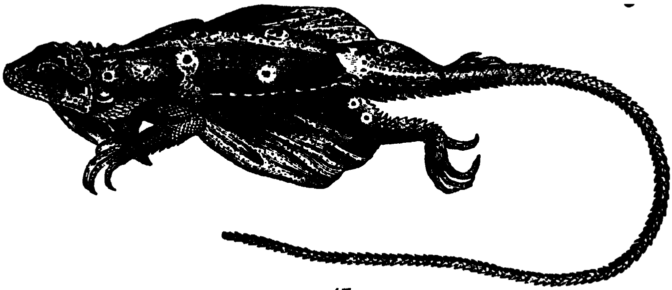
Varans, or *monitors*. The *varan* of the Nile (Monitor niloticus), is very destructive to the eggs and the young of the crocodile. The *monitor* of

Guiana (Thorictis dracæna), is about 5 feet long, and resembles the crocodile. Our *gray* and *green lizards* (Lacerta agilis and L. viridis), are harmless, pretty, little, active creatures. The *chameleon* (Chamæleo Africanus, fig. 46), is a most extraordinary animal, which, among other peculiarities, is distinguished by the faculty of presenting remarkable changes of color, varying through different shades of yellow, red, gray, brown, violet, and dull inky-blue.

46.

The *flying dragon* (Draco volans, fig. 47), a small Javanese lizard, is characterised by a thick fleshy tongue, and a membranous fold or expansion along each flank, by which it sustains itself in the air, whilst it leaps from branch to branch; but it cannot use this species of bat-wings with sufficient force to fly like a bird or bat. To this suborder belong also the *crested basilisk* (Basiliscus mitratus), the *Iguanas*, which grow several feet long, (usually four to six, including the tail,) and of which the flesh is very palatable; the graceful little *anolis;* the *radiate lizard* (Stellio); and, finally, the *gecko*, a nocturnal, sluggish, repulsive creature, with fingers very much expanded towards the end, and furnished underneath with little folds of skin, which appear to perform the function of sucking, and which enable the animal to run along the smoothest surface, to creep up walls, and to traverse ceilings with the back downwards. When in pursuit of its insect prey, the gecko occasionally utters a kind of chuckling cry, which has led to the name of the animal. Of this hideous reptile, one species (Platydactylus), is found in the south of Europe.



47.

The families *chalcidæ*, or *snake-lizards*, and *Scincidæ*, or *Scinks*, form the transition from the order of lizards to that of serpents. The members of these families have a short, mostly forked tongue; the body is usually cylindrical, and extremely elongated or snake-like; in some destitute of limbs, and in most with the limbs in a rudimentary state, or at all events only little developed. Among them we notice the *Scheltopusic*, which has no fore-legs, and for hind-legs only scaly appendages; the brittle *glass-snake*

(Ophiosaurus); the *scink* (Scincus), formerly held in great repute for its supposed medicinal virtues; the *common blind worm* (Anguis fragilis), which brings forth its young alive, and in its whole internal structure differs from the snakes, to which in external appearance it bears a great resemblance; and the *Amphisbœna.*

Third Order. Ophidia (*the Serpent Tribe*).

126. The serpents present great similarity of conformation and structure. Their head is small, but the mouth is very dilatable, as the bones which form the jaw are not united, but simply connected by flexible cartilages. Hence they can swallow animals larger than themselves. Nature has endowed many of them with a venomous apparatus; the poison is secreted by glands, which pour it out through an excretory duct, in the neighbourhood of one of the maxillary teeth of the upper jaw, which is sometimes pierced by a canal, sometimes only channelled by a furrow. They frequently cast their skins; they are most of them natives of hot countries. The following are some of the more important members of the serpent tribe, viz.:—

The *South American coral snake* (Ilysia scytale), of a beautiful coral red, variegated with black bands; the *cylindrical coral snake* (Cylindrophis). The monsters of the order, however, are the *boas*, certainly not venomous, but of enormous size, viz., from 30 to 40 feet long, and of incredible muscular strength, able to destroy the most powerful quadrupeds, by compressing them within their mighty folds. The *boa constrictor* and the *marine boa* (B. marina), are natives of Brazil; the *tiger boas*, or pythons (Python tigris and bivittatus) of the East Indies are not uncommonly exhibited in menageries.

Various specimens of the *colubers* (Colubridæ), a section of harmless snakes, are not unfrequently found in Europe, as *e. g.*, the *common ringed snake* (Coluber natrix), which is steel-gray, with white and black spots on the belly, and a yellow ring about the neck; the *yellow water-snake* (C. flavescens), from 3 to 5 feet long, is especially frequent in the Schlangenbad in Germany, which has received its name from it.

48.

One of the most beautiful of the tribe is the South American *green tree-snake* (Dryophis).

Among the *venomous serpents* (Venenosi), we find in the Indian Ocean the *marine snakes* (Pelamys and Hydrophis), with vertically flattened tails, which they employ as rudders in steering their course through the water; and in Brazil the cinnabar-red, and black and white ringed *snake*, or *coral-viper* (Elaps corallinus). One of the most dangerous of the venomous tribe is the *Indian naja*, or *hooded* or *spectacled snake* of India, (Naja tripudians, cobra di capello), which performs an important part in the idolatrous rites of the natives, and

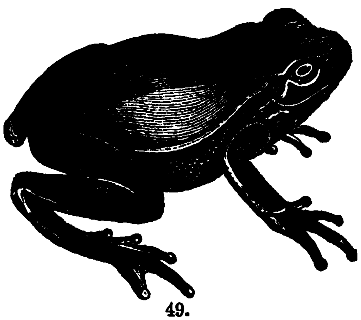
also in the juggling tricks of itinerant mountebanks. This creature when excited has the power of raising the loose skin of the neck into a sort of collar or hood behind its head. The jugglers, before exhibiting their tricks with it, contrive to exhaust the venom by causing the animal repeatedly to bite a piece of cloth. They also know how to render the snake harmless by pressure on the brain.

The *common viper* or *adder* (Vipera berus), is an inhabitant of our own country; it attains a length of about 2 feet, and is subject to great differences in color; thus we have black, red, and blue-bellied varieties. The bite of the viper speedily kills the small animals upon which it feeds; under certain circumstances it may become dangerous also to man; in case of accidents of the kind it is always advisable therefore to have recourse to suction, excision, or cauterising of the wound. The most common of the venomous serpents of the Antilles and Brazil are the *lance-headed vipers*, or *cophias* (Trigonocephalus). The *rattle-snakes* of America (Crotalus horridus of South America, fig. 48, and Crotalus durissus of North America), are equally formidable. These reptiles are distinguished by a peculiar appendage to the tail, consisting of a number of thin horny cells, loosely articulated to each other, and producing a rustling or a rattling noise when shaken; the animal vibrates this appendage when irritated or alarmed, and gives thereby timely warning of its approach. The power of fascinating smaller animals, which is attributed to the rattle-snake, is said to be the effect of a stupifying odor emitted by it.

FOURTH ORDER. BATRACHIA (*the Frog Tribe*).

127. The batrachian reptiles have a naked skin, and no ribs. At first, when coming from the egg, they resemble fishes both in their external form and internal structure; and it is only by degrees, and after having passed through a series of metamorphoses, that they acquire the form which they ultimately preserve. Some of them retain the gills of the tadpole state through life.

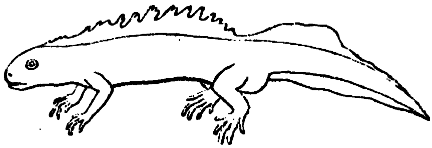
The first section of this order contains the ecaudate (tailless) *frogs* (Ranidæ), which are quite destitute of any tail, but have very long hind legs, which constitute the chief instruments in the progression of the animal. We find here the *American pipa* (Pipa americana), which bears her eggs and young for a considerable time on her back; the beautiful *green tree frog* (Hyla arborea, fig. 49), which is often kept in glasses to indicate approaching changes in the weather, as the male, which is distinguished from the female, by its black throat, utters a croaking noise at the approach of rainy weather. The *French frog* (Rana esculenta), is not quite a stranger in our island, while the *grass*, or *common frog* (R. temporaria), is very plentiful. Both species lay their black eggs surrounded by a slimy substance in lumps in the



49.

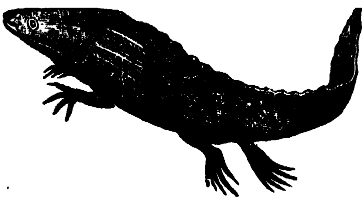
water of our ditches and ponds in early spring. The footless and long-tailed young frogs coming from the eggs, are called *tadpoles*. The *femora, or hind-legs*, are the only part of the green water frog that is eaten. Of exotic frogs we notice the *glossy frog* (R. micans), the *bull-frog* (R. mugiens), and the *horned frog* (R. cornuta.) The transition from the frogs to the toads is formed by the *fire-frog* (Bombina), and the *nurse-frog*, or *obstetric toad* (B. obstetricans), which carries her eggs coiled round her legs. The *toads* (fig. 50), lay their eggs in long strings, and are rather terrestrial than aquatic animals; they are plump, sluggish, ugly, nocturnal creatures, with their bodies mostly covered with warts; but their eyes are beautifully set in a gold-like frame. Although almost all of them emit a disagreeable garlic smell, and secrete a slimy foam, yet none of them are venomous. The most commonly known of the toads are, the *garlic toad*, or *garlic-smelling toad* (Bufo fuscus), and the *reed*, or *cross toad* (B. calamites), the former common, the latter rare in England. The *common land toad* (B. cinereus), and the *giant toad*, or *bull-frog* of the Anglo-Americans (B. gigas), are found on the continent.

50.



51.

The second section of batrachian reptiles includes the *salamanders* (Caudata). Some of these lose their gills in the course of their metamorphoses, as the *salamander* (Salamandra), spotted with yellow and black, and erroneously deemed venomous; and the *water newt* (Triton, fig. 51), which has a dentate crest along its back. In others (the *Proteidæ*, or *perennibranchiate* Batrachians), the gills remain during the whole of life. To this latter section belong the *eel-salamander* (Amphiuma), the *gilled salamander*, or *axolotl* (Siredon, fig. 52), the *Proteus anguineus*, which inhabits the underground lakes of the Tyrol; and the curious *Lepidosiren*, which approaches the most nearly of any of this group to the class of fishes.



52.

The last section of batrachians is formed by the curious family of *Cœciliadæ*, natives of America and Java, which combine with the form of serpents the naked skin and imperfectly developed ribs of frogs. In these animals the eyes are completely hidden beneath the skin; hence their name.

The Fourth Class. Fishes (Pisces).

128. Fishes live exclusively in the water. They have no lungs, and

breathe by *gills* only; these gills consist of a number of projecting and very vascular membranous plates, situated on both sides of the head, and protected by a moveable flap, which is called the *operculum*, or *gill-cover*. In the respiratory process, the water imbibed through the mouth is, by a movement of deglutition, forced through the opening between the *branchial arches*,* and arrives thus at the gills, where the air which it holds in solution, is brought into contact with the blood; this suffices to support the respiratory process; there are some fishes, however, which, finding this insufficient, rise from time to time to the surface to breathe air. The water, after bathing the surface of the gills, escapes outwards by the opening of the latter.

The blood of fishes is red, but its temperature does not exceed that of the water in which the animal lives.

A peculiarity in the organisation of most fishes is the existence of the so-called *swimming bladder*, a kind of bag filled with air, and compressible at will, and which, according to the space that it occupies, gives to the body of the fish a specific gravity, equal, superior, or inferior to that of the water, and thus enables it to remain in equilibrium, to rise, or to descend in this liquid.

The muscles of fishes are white, and are not separated in bundles by membranous envelopes; their movements are accordingly imperfect.

The skeleton of fishes is only imperfectly developed; the limbs of the other vertebrated animals being represented by *fins*, which are divided, according to their respective position, into *pectoral*, *ventral*, *dorsal*, *caudal*, and *anal*; the fish being placed the higher in the scale of classification, the more nearly the fins correspond in number and position to the limbs of the higher animals. The fins have all very nearly the same structure, consisting almost invariably of a membranous fold, supported by bony or cartilaginous rays.

The skin of some fishes is almost entirely bare, but in the great majority of them it is covered with scales or horny plates, which latter frequently rise in tubercles and spines.

Fishes multiply by means of eggs, which are in many of them produced in immense numbers, several hundred thousands being often produced at a time; nay, the *roe* of a single female of the cod tribe has been estimated to contain nine millions of eggs! In the males we find the so-called *milt* or *soft roe*. Fishes are very serviceable to man in a variety of ways; the flesh of the immense majority of them is eatable; and the bones, or gristle, scales, skin, swimming-bladder, and fat, are also turned to profitable account.

* The *branchial arches* which support the gills, are four pairs of bony arches, passing off from the central portion of the hyoid apparatus, and first directed backwards, then curving upwards and inwards, and fixed finally to the base of the cranium by a series of small connecting bones, termed the superior pharyngeal bones.

129. Classification of Fishes.

A. Cartilaginous Fishes—Skeleton Cartilaginous.			B. Osseous Fishes—Skeleton Bony.			
Pectoral and Ventral Fins.			Bones of Upper Jaw			
Present.		Absent.	Soldered.	Moveable.		
				Gills set in tufts.	Gills Pectiniform.	
1. Order—Gills fixed, Jaws moveable. Plagiostomi.	2. Order—Gills free. Eleuthero-branchii.	3. Order—Gills fixed. Jaws soldered Cyclostomi.	4. Order—Gills fixed. Plectognathi.	5. Order—Tuft-gilled. Lophobranchii.	6. Order—Soft-finned, or Soft-rayed. Malacop-terygii.	7. Order—Spiny-finned, or Spiny-rayed Acanthop-terygii.

First Order. Plagiostomi (*the Shark* and *Ray tribes*).

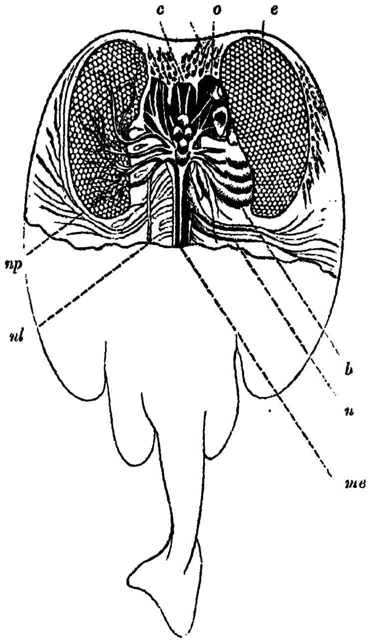
130. Among the *Sharks* or *Squalidæ*, the most voracious of all sea monsters, we notice the *white shark* (Squalus carcharias), and the *Notidamus* (S. maximus), which latter sometimes attains a length of 36, and even 40 feet. The mouth of the shark is armed with several rows of formidable pointed teeth, which are found implanted even on the tongue. The white shark will often for days follow in the wake of ships, in expectation of prey. In many places (for instance in the valley of the Rhine, near Alzei), thousands of shark's teeth are found, the petrified remains of an ancient world. The shark family contains many other genera, more or less departing from the ordinary type; among these we mention the *hammer-headed shark* (Zygæna malleus), which has its snout prolonged in the form of a double-headed hammer, with an eye in the middle of each extremity; the *pristis*, or saw-fish, which is characterised by the extension of its snout into a long, flat, serrated blade; the reddish and spotted *dog-fish* (S. canicula), which attains only a length of two feet.

The tuberculated skin of the shark is manufactured into shagreen, and abundance of oil is extracted from the liver.

The *rays*, or *Raidæ*, are distinguished especially by their flat, orbicular shape, and by the thorny and spinous processes with which many of them are armed.

The flesh of the *skate* (Raja batis) of the North Sea, is very palatable. The *electric ray*, or *Torpedo*, is remarkable for its power of giving electric shocks; the electric apparatus of this animal (fig. 53), consists of a multitude of membranous vertical tubes, closely packed together like the cells in

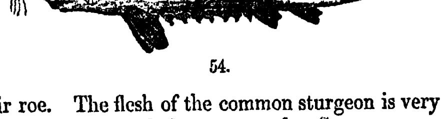
a bee-hive, and subdivided by horizontal partitions into small cells filled with mucous matter.



[Electrical apparatus of the Torpedo:—*c*, brain; *me*, spinal chord; *o*, eye and optic nerve; *e*, electrical organs; *np*, pneumogastric nerves, proceeding to the electric organ; *nl*, branch from the preceding, covering the lateral nerve; *n*, spinal nerves; *b*, gills.]

Second Order. Eleutherobranchii seu Chondropterygii Branchiis Liberis.

131. This small order may be arranged under two families, viz., the *Acipenseridæ*, or *Sturgeons*, and *Chimæridæ*, or *Chimæras*. The former contains some of the most useful fishes, as, for instance, the common *Sturgeon* (*Acipenser Sturio*), and the *Great Sturgeon* (*Acipenser huso*), both valued on account of the excellent *isinglass* which is obtained from their air-bladders, and the *Caviare* which is prepared from their roe. The flesh of the common sturgeon is very palatable, that of the great sturgeon is much less esteemed. Sturgeons are



54.

more abundant in some of the continental rivers than in those of Britain; they are particularly numerous in the rivers which fall into the Black and Caspian Seas. Their capture and cure form an important branch of industry among the Cossacks of the Don.

The most common species of the *Chimæras* is known under the name of the "king of the herrings."

Third Order. Cyclostomi.

132. The fishes of this order are the most imperfect of the whole class; and may be properly looked upon as the connecting link between the vertebrated and invertebrated sub-kingdoms. They can hardly be said to have a vertebrated skeleton, since even in the highest among them, the vertebral column is replaced by a sort of cartilaginous cylinder, in which no definite division into segments can be traced; and in the lowest, this cylinder consists simply of a membranous bag, containing a gelatinous semi-fluid substance. The body is usually prolonged, and nearly cylindrical, and terminated by a circular mouth adapted for suction. To this order belong the *lamprey* (Petromyzon marinus, fig. 55), the *river lamprey* (P. fluviatilis), which is often caught and pickled in the north of Germany, the *lamprillon*, or *lamproyon* (P. branchialis), with hidden eyes, and the blind *hag* (Myxine), which secretes enormous quantities of mucus from its surface.

55.

Fourth Order. Plectognathi.

133. This small order forms the connecting link between the cartilaginous and the osseous fishes. It contains most singularly shaped fishes, whose skin is often covered with spines. As the most remarkable among them, we mention the *globe-fishes*, or *porcupine-fishes;* the former name has been given to them from their power of distending themselves into a spherical form; the latter from their spinous covering; when distended they float along the water with the back downwards. The *globe-fish* tribe contains three genera, viz., the *Diodon*, or two-toothed, the *Triodon*, or three-toothed, and the *Tetrodon*, or four-toothed. The *orthagoriscus*, or *sun-fish*, looks like the anterior half of a fish cut in two in the middle; it has the power of floating with its head and eyes above water, but not of distending itself with air like the *globe-fishes*. The *trunk-fishes*, or *Ostracions*, have the head and body covered with an inflexible cuirass formed of angular plates of bone. The *unicorn-fish* (Balister monoceros), and the *Balister pencilligerus*, which is remarkable for the appendages with which its body is furnished, belong also to this order. All the fishes of this order are inhabitants of the seas of warm regions.

Fifth Order. Lophobranchii (*Tuft-gilled fishes*).

134. The fishes of this order are mostly of small size, and often without

flesh; their gills are set upon the branchial arches in small round tufts arranged in pairs. As examples, we notice the *needle fish*, the *Hippocampus*, the *pipe-fish*, or *Syngnathus*, the *Pegasus*, and the *Sea-Dragon*.

Sixth Order. Malacopterigii, or Soft-Rayed Fishes.

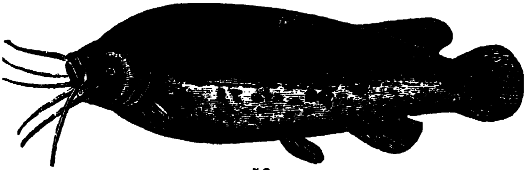
135. This order, which is the largest of all, includes the most important families both of the sea and fresh-water fish, and in the capture, curing, and exportation of which thousands of men are constantly employed. The most important family of the order is that of the *salmons* and *trouts* (Salmonidæ), which is characterised by having all the rays of the first dorsal fin soft or jointed, and the second dorsal consisting simply of a fold of skin enclosing fat. The mouth in the Salmonidæ is wide, and mostly armed with hooked teeth. Most of them frequent the estuaries of rivers, and ascend the stream at regular periods to deposit their spawn in its higher parts. The most valuable of the family is the *common salmon* (Salmo salar), of our own rivers, which is highly esteemed for its fine flavored red flesh. The *Lake trout* (S. lacustris), inhabits the large lakes in Switzerland; and the *common trout* (S. trutta), a fine fish, beautifully marked with red spots, lives in the clear cool water of mountain streams. The *capellan* (Mallotus), a small sea fish, congregates in enormous shoals, and forms the principal food of the cod and ling. The *thymallus*, or *grayling* (S. thymallus), whose flesh is very palatable, is found in the Danube; and the *lavarets* (S. lavaretus and marænula), are common in the Lake of Constance.

The *herring* tribe is also very important. The *common herring* (Clupea harengus) inhabits the north seas; the method of curing this fish was first practised by Beukel in 1397. The estimated annual capture is 1000 millions, and about an equal number are supposed to fall a prey to other fishes. The *anchovy* (C. enchrasicholus), and the *sardine* (C. sardina), replace the herring in the Mediterranean. The *pilchard* abounds on the Cornish coast. The *shad* (C. alosa), which ascends the rivers in the early part of the summer, is esteemed a great delicacy, but should be eaten with caution.

The fishes of the *pike* family are little known; many of them are inhabitants of the sea, as the *gar fish*, or *sea pike*, the *exocetus*, or *flying pike*, or *flying fish*, which is remarkable for the enormous development of its pectoral fins, upon which the animal may support itself a short time (about 30 seconds) in the air. The *common pike*, or *river pike* (Esox lucius), with broad depressed head and black-spotted fins, is esteemed for its palatable flesh. It is most voracious. It is a very long-lived fish. It attains a weight of from 12 to 40 pounds, and a length of from 4 to 8 feet and more.

The *cyprinidæ*, or *carp tribe*, are characterised by their small mouths, and by their feeble and generally toothless jaws. They mostly inhabit ponds and sluggish streams, and live, some on aquatic plants, some on worms, and some, as the *barbel*, on small fishes. Among them we notice the *common carp* (Cyprinus carpio), one of the commonest and most palatable of our fresh-water fish; the *loach* (Cobitis); the *barbel* (C. barbus); the *tench* (C. tinca); the *gudgeon;* the beautiful little *gold fish* (C. auratus), imported from China, and frequently kept in glasses and vases; the *roach* (C. rutilus); the *bleak*

(C. alburnus), a small fish, 3 or 4 inches long, whose minute silvery scales are used in the manufacture of glass pearls.

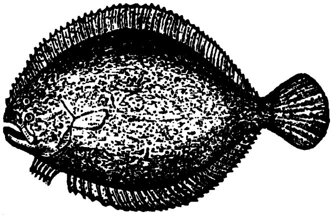


56.

The largest of our fresh-water fish is the *silure*, or *silurus* (Silurus glanis), the head of the *siluridæ*, or *silure* tribe, to which belongs also the *malapterurus*, or *electric silurus* of the Nile (Silurus electricus, fig. 56).

The fishes belonging to the family of the *gadidæ*, or the *cod* tribe, have mostly a long body, rather slender, and covered, with the exception of the naked head, with soft scales. They live for the most part in the seas of cold or temperate climates, and are most highly esteemed for the wholesomeness and good flavor of their flesh. The most important of the family are the *cod* (Gadus morrhua), the *ling*, and the *haddock*, which are eaten partly fresh, partly preserved; the haddock is considered the most delicate of the three when fresh; but it does not take the salt as well as the cod and ling. From the liver of the cod an oil is obtained, which has of late years acquired a high reputation as a remedial agent in scrofular and tubercular diseases. Other members of the *cod* tribe are the *whiting*, the *hake*, the *rockling*, the *coal-fish*.

The *flat-fish*, or *Pleuronectidæ*, have still more delicate flesh than the *gadidæ;* among them we mention the *sole* (Pleuronectes solea), the *turbot* (Pl. maxima, fig. 57), and the *plaice* (Pl. platessa, fig. 58).



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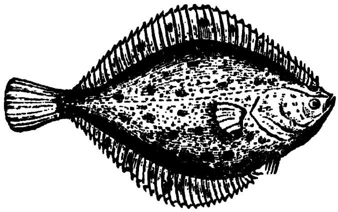
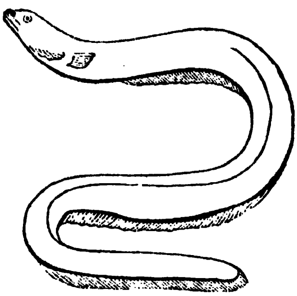


58.

The *remora* or *sucking-fish* (Echineis) is provided with a singular apparatus, which enables it to adhere with great firmness to foreign bodies; this is a flattened disc which covers the upper part of the head, and is composed of a certain number of cartilaginous and moveable plates, directed obliquely backwards.



59.

The *Murænidæ*, or *eel* tribe, are characterised by their long, slender, snake-like bodies, covered with a soft skin, and very minute, and often almost invisible scales. The fins are very small, and are partly wanting. The best known are the *river eel* (Muræna anguilla), the *sea eel* (M. helena), both excellent table

fish; the *electric eel* of South America (Gymnotus electricus, fig. 59); the *sand eel* (Amnodytes), which is found in the sands on the shores of the North Sea and the Baltic, and is used by fishermen as a bait; the *snake-fish*, and the *ribband-fish* (Leptocephalus or Morris.)

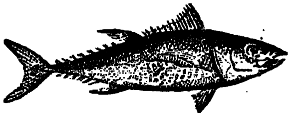
SEVENTH ORDER. ACANTHOPTERYGII, OR SPINY-RAYED FISHES.

136. This order also contains a number of important families; the spinous fin-rays constitute the distinguishing characteristics. Among the most remarkable members of the order, we notice the *sea-wolf* or *wolf-fish* (Anarrhicas lupus), a voracious animal, which attains a length of from 6 to 7 feet; its flesh is palatable and wholesome; the *gobies*, which are common in the lagoons of Venice, are very solicitous about their young. Peculiarity of conformation and appearance distinguishes the genus *Lophiadæ*, or *anglers*, or *frog-fishes*, among which we mention the hideous *Sea Devil*, and the *Chironoctes*, or *Hand-fish*. The genus *Scarus*, or *Parrot-fish*, and the *Sparidæ*, or *Sea-Breams*, are remarkable for the beauty and brilliancy of their tints.

The *Perch* (Perca fluviatilis), is one of our most common fresh-water fishes; the color of its pectoral, dorsal, and caudal fins is red, it is marked with black transverse bands over the green-colored back; its flesh is very palatable. To the *Percidæ* belong also, the *Basse*; the *Pike-Perch* (Lucioperca); the *Stone-perch* (Acerina cernua); the *Trachinus*, or *Weaver*; the *Uranoscopus*, or *Star-gazer*, so called because its eyes are situated in the crown of the head, and directed towards the heavens; the *red Mullet*, *Mullus*, or *Surmullet* (Mullus surmuletus), held in high repute among the epicures of ancient Rome, who paid as much as 40 pounds sterling for this fish.

Nearly allied to the Perches are the *Triglæ*, or *Gurnards*, among which we mention the *grunting* or *croaking Gurnard* (Trigla hirundo), and the *flying Gurnard* (Dactylopterus volitans).

The *Gasterosteus*, or *Stickle-back*, is an active and rapacious little fish, which does great injury in our rivers by devouring the spawn of other fishes. Among the most important fishes of the 7th order are the *Mackerel* (Scomber, fig. 60), and the *Tunny* (Thynnus), the largest of the edible sea-fishes, which occasionally attains a length of 15 feet and above, and is very plentiful in the Mediterranean; its flesh, both fresh and salted, forms a considerable part of the food of the common people of the shores of the Mediterranean, and the Tunny fishery constitutes an important branch of industry in these parts.



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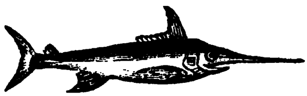


61.

Another remarkable group of the *Mackerel* tribe consists of the *sword-fish* (Xiphas, fig. 61), and its allies, which have the muzzle elongated into a spike terminating in a sharp point, and constituting a most formidable weapon. The *Pilot-fish* (Naucrates ductor), is commonly regarded as a guide

to the Shark. The *Surgeon* (Acanthurus) is armed on both sides with a sharp cutting spine. Among the so-called *Scaly-finned* fishes, we find the *Chætodons*, beautifully colored fishes of singular figure, abounding in the tropic seas, and among which we mention the *Chætodon rostratus*, and the *Archer* (Toxotes jaculator), inhabitants of the seas around Java, and of the Indian Seas, and which are remarkable for the manner in which they obtain their insect prey, viz., by shooting at them small jets of water from their long snout.

One of the most remarkable of all fishes is the *Anabas*, or *climbing* fish of the South East of Asia and the adjacent islands, and of Southern Africa. This curious animal can exist a considerable time out of water, and can migrate over land from one pond or stream to another; in the course of its journey it climbs up steep banks, and even trees, with the assistance of its spiny rays. The *big-headed mullet* (Mugil cephalus), which inhabits the mouth of the rivers that flow into the Mediterranean, and the *snipe-fish*, or *sea-pie* (Centriscus scolopax), a fine flavored fish, bring up the rear of the order.

B. Invertebrate Animals (Avertebrata).

137. The *invertebrata* occupy a much lower station in the scale of creation than the vertebrated animals. The organs of *vegetative* life preponderate in them more or less over those of *animal* life; and in some of the lowest orders of them, even the former are so imperfectly developed that doubts were long entertained whether they ought to be placed in the animal or in the vegetable kingdom.

The one organ which is invariably present in the *invertebrata*, from the highest order of them down to the lowest, is, of course, the stomach or alimentary apparatus; the lowest of the invertebrated animals are, so to say, *all stomach*, their body consisting of a simple digestive bag, or sac;—but as we ascend higher in the scale, we find a stomach distinct from the body, and besides this, tubiform structures, which correspond to the liver in the higher classes of animals, vessels containing colorless blood, and nervous ganglia—in short, all the organs which we designate in man as *viscera*. Hence the higher orders of the invertebrated series may be termed also *visceral animals*.

But, even in the very highest orders of invertebrated animals, there is hardly the least approach to that collective complex system of bones, muscles, and nerves, which characterises the vertebrated animals, and gives to them a definiteness of shape, a vigor of motion, and an intelligent will, such as none of the invertebrata possess.

The organs of the senses, by which alone the relations of the animal with the outer world are established, are also only most scantily developed, or even altogether absent, in the invertebrated series.

138. The soft mass of the viscera which constitute the bodies of invertebrate animals, is well protected against external injuries; being in some enclosed in a series of tough gristly or horny rings; in others within a calcareous shell.

The invertebrated animals are characterised also by their general com-

parative diminutiveness. The majority of them are barely visible to the naked eye, and the large *Cuttle-fish* and the *Tridacne* or *Giant Clamp-shell* alone attain anything like large dimensions.

But the inferiority in size and organisation of the invertebrata, as compared with the vertebrated series, is compensated in a measure by the astonishing multiplicity of genera and species, and the almost *incredible number of individuals* found in the invertebrate sub-kingdom. It seems as if nature intended to show, by this infinite number of ever new, ever varying creations, with what ease she can accomplish the same objects in an infinite variety of forms and organisations.

139. The usefulness to man of any individual animal of the invertebrate series, is of the most insignificant kind, compared to that of the higher animals. In fact, the invertebrata acquire importance only from their numbers, and most of them are rather injurious than profitable to man. Millions of the most diminutive of them are waging incessant war against our provisions, our clothes, our habitations, and even our bodies; and many of our customs and domestic arrangements are simply instinctive means of defence, adopted unconsciously against the depredatory incursions of these infinitely small foes.

Most men would no doubt willingly renounce lobsters, shrimps, and oysters, and honey, silk, wax, shell-lac, and other products of the lower tribes of animals, if exemption might be purchased thereby from the attacks and ravages of the locust, the caterpillar, the moth, the grub, the maggot, the gnat, the mosquito, the bug, the flea, and the countless myriads of other vermin that prey upon man in one way or another.

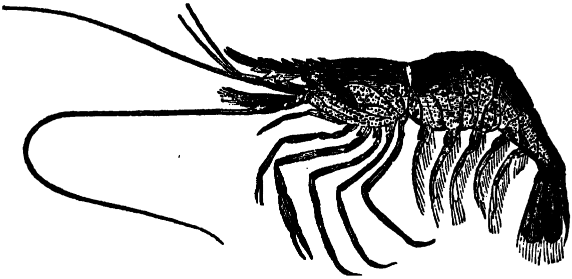
But the destruction and removal of these lower orders of animals, would involve the ruin and destruction of millions of animals of the higher orders, and a total disarrangement of the universal harmony of nature; in fact, no individual link, however so insignificant apparently, can be abstracted from the great chain of organic life, without breaking the whole chain.

We divide the invertebrated series into ten classes, viz.:—*Crustacea*, *Insects*, *Arachnida*, *Annelida*, *Mollusca*, *Entozoa*, *Echinodermata*, *Acalephæ*, *Polypifera*, and *Infusoria* or *Polygastrica*. Under the class *Polypifera*, naturalists generally include a group of very minute marine animals, which, owing to their extreme minuteness, have not as yet been satisfactorily examined, and to which D'Orbigny gave the name of *Foraminifera*.

Fifth Class. Crustacea.

140. The tegumentary skeleton of the Crustacea is generally very firm and hard, containing a considerable proportion of carbonate of lime. The body is divided into two distinct portions, the *cephalo-thorax* (made up of the head united to the thorax, and covered with a shield), and the abdomen, which latter usually presents the appearance of a tail. In some of them, in the Sandhopper and woodlouse, for instance, the head is distinct from the thorax. The Crustaceans breathe by *bronchiæ* or external gills, or by membranous vesicles, or by the general surface. The animals of this class possess the reproductive or recuperative faculty (the faculty of reproducing lost parts), in an eminent degree.

The highest order of Crustaceans, and the one most useful to man, is constituted by the *Decapoda* (ten-legged, or ten-footed). The *lobsters, crabs, cray-fish, prawns, shrimps*, in short, nearly all the edible species, belong to it. The first pair of legs is transformed, in these animals, into powerful claws or pincers. We notice here more particularly, the *prawn* (fig.



62.

62), the *shrimp* (Cancer grangon), the *lobster* (Astacus marinus), which sometimes attains a length of two feet; the *Palinurus* or *Spiny lobster* (the *Locusta* of the ancient Romans); the *Hermit Crabs* or *Paguridæ*, whose tail is destitute of a calcareous envelope, which makes them resort to various artificial methods for the protection of their soft part; most of them seek for this purpose univalve shells, in which they take up their abode, attaching themselves to the interior by a sucker, with which the tail is furnished at its extremity. In fresh water we find only the *river cray-fish* (Astacus fluviatilis), of a brown color, but which, on the animal being boiled, assumes a lively red tint. This crab casts its shell from time to time, and forms a new one.

A special suborder of the Decapoda is formed by the *Brachyoura* or short-tailed decapods, to which the name of *crabs* is commonly applied. Like most individuals of the class, they easily lose their claws, which are as easily restored. There are many species of crabs, as e.g. the *Carcinus mænas*, or *common small edible crab;* the *Maia*, or *Sea-Spider;* the *Cancer pagurus*, or *common large edible crab;* the *river-crab* of Southern Europe (Thelphusa); the *Land-Crab* of the Antilles (Gecarcinus), remarkable for the migration which it makes; viz., when the season arrives for the deposition of the eggs, it moves towards the sea in large companies, and returns subsequently inland accompanied by the young; the *pea-crab*, which, at least part of the year, resides inside various bivalve shells, such as mussels, &c.; and the *Podophthalma*, which is extremely remarkable for the length of its eye-bearing foot-stalks.

The *Isopoda* form another order of the Crustaceans; most of the animals of this order are aquatic, but one group is terrestrial. The terrestrial Isopods, of which the common *wood-louse* is a very familiar example, frequent for the most part damp and dark situations, such as cellars, caves, holes in walls, &c. They have the power of rolling themselves into a ball; the *armadillo pustulatus* belongs to this section. Many of the aquatic Isopods

are parasitic upon other animals, very frequently upon larger Crustaceans, as is the case, for instance, with the *Bopyrus*, which affixes itself to the common prawn. The *Myriapoda* bear considerable resemblance to the Isopods; but most naturalists place them now in a distinct class by themselves, we will, however, here include them among the crustaceans. We notice among them the *Centipede*, or *Scolopendra*, of which the yellow variety is luminous in the dark; and the *Millipede*, or *Iulus*, with a long and cylindrical body, consisting of between forty and fifty segments, many of which bear two pairs of almost thread-like legs.

To the order *Amphipoda* belong, the *Water-flea* (Gammarus pulex), the *Sand-hopper* (Talitrus locusta), and the *Coryphium*, which is remarkable for its very long antennae, and its predaceous habits.

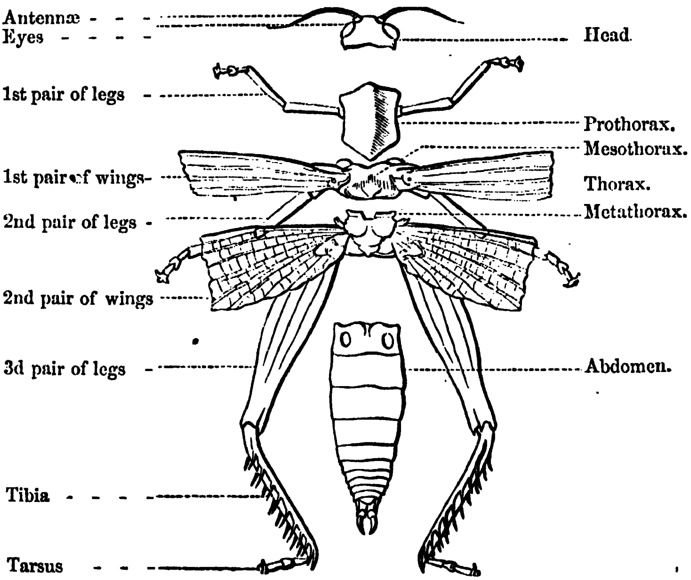
To the order *Læmodipoda* belong the *Cyamus balænarum*, or *Whale-louse*, and the *Spectre-louse* (Caprella Phasma). The *Branchipus* belongs to the order *Phyllopoda;* the *Daphnia pulex*, or *Monoculus*, or *Arborescent Water-flea*, to the order *Cladocera;* the *Cypris*, to the order *Ostrapoda*. The Crustaceans of the order *Siphonostoma*, are all parasitic upon fishes, aquatic batrachians, &c., and many of them are known under the name of *fish-lice;* we mention of them the two genera *Argulus* and *Caligus*. The order *Xiphosura* contains only a single genus, viz., the *Molucca crab*, *limulus* or *king-crab*, which attains sometimes a length of two feet, and is characterised by a long horny process of the posterior shield, which some of the Malays use as a point for their arrows. The *Cirrhopoda*, or *barnacle* tribe, were formerly classed with the mollusks, and are now by many naturalists placed in a class by themselves. Most of them have a shell composed of several pieces, and are affixed to rocks, posts, or other solid masses. Among them we notice the *lepas*, or *barnacle*, and the *balanus*, or *acorn-shell*, called also the sea-tulip, and of which several species attach themselves to fucus, to crabs, and to the skin of the whale.

SIXTH CLASS. INSECTA (INSECTS).

141. We come now to the ever-active all-animating world of insects, which everywhere people the earth, the waters, and the air. Whilst the grubs and larvæ hide in the earth and in the chinks of rocks, or frisk about in the water, or sit ensconced in the very core of trees, piercing and gnawing the wood in every direction, the perfect insects swarm in countless myriads in the air, or flit restlessly to and fro in the performance of some task assigned to them by nature.

He who would contemplate and observe the busy life of this miniature world, let him stretch himself on a warm summer afternoon on the green turf of the brink of brook or river, and he will find himself in the midst of a stage whereon a numerous community of beings of the most varied kind, from the plain, ever-busy ant, to the idle, gorgeously painted butterfly, are performing as it were around him the ever changing comedies and tragedies of their brief existence. There booms and buzzes the beetle; the industrious bee is busy collecting honey and wax; the caterpillar is feeding on the green leaf; the butterfly roams from flower to flower; the flies and gnats are swarming and dancing in the air.

The insects are characterised by the division of the body into three distinct parts, viz., the *head*, which always consists of a single piece; the *thorax*, which always consists of three rings or segments; and the *abdomen*, which is composed of a considerable number of rings or segments (frequently as many as nine), moveable upon each other. Each one of the three thoracic segments has a pair of members or appendages attached to it, so that every insect has 3 pairs of legs (see fig. 63). Along the body, on both sides, are a



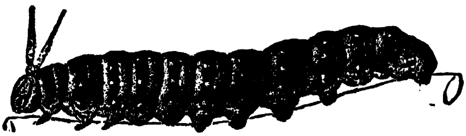
63. Anatomy of the external skeleton of an insect.

number of air-conveying canals or respiratory tubes (tracheæ), which communicate with the interior, and ramify minutely in the substance of the organs. Insects are provided with highly developed senses; there can be no doubt but that they possess the senses of smell and hearing, as well as those of sight, taste, and touch, although we have not been able as yet to discover distinct apparatus for the senses of smell and of hearing (at all events, not in the greater part of these animals), and are still very much in the dark indeed, regarding the apparatus for taste. But the organ of sight has been studied more closely. In general, the eyes of insects, though appearing single at first sight, are, in reality, formed by the aggregation of a multitude of hexagonal facets, or small eyes, having each a cornea, a conical-shaped vitreous body, a layer of coloring matter, and a separate nervous filament proceeding from a bulbous expansion of the same optic nerve. The antennæ and the buccal apparatus are also highly developed in insects, and present very considerable variety of form and structure.

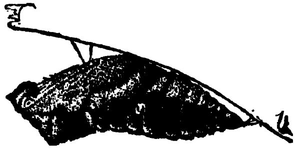
The wings of insects arise always from the last two segments of the

thorax. In several kinds of insects these organs are not present. In the limbs of insects, we may distinguish a haunch composed of two joints, a thigh, a shank, and a kind of finger, called *tarsus,* and which is divided into from two to five joints, and terminated by claws.

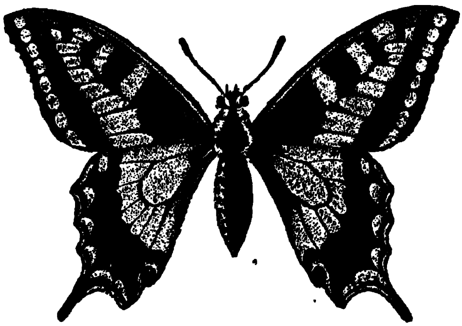
A most curious phenomenon presented by the insect class, are the changes which insects, in general, undergo before arriving at a perfect state, and to which the name *metamorphosis* has appropriately been given. From the egg slips out the *Larva,* which is always more or less vermiform, and passes sometimes by the name of *caterpillar,* sometimes by that of *worm.* The Larva is very voracious, grows rapidly, casts its skin repeatedly, and passes after a longer or shorter time into the *pupa* or *Chrysalis* state. In this second period of its existence, the animal takes no food, and remains motionless, sometimes the pupa is covered simply by a thin pellicle; sometimes the skin cast off last, dries up, and forms a hard oval envelope for the pupa. Whilst the insect is in this state of apparent repose, active operations are going on within the body, which result in the complete development of the entire organisation; when the evolution is finished, the insect breaks through the integumentary envelope enclosing it, spreads its wings, which speedily acquire firmness, and makes its appearance in the world as a *perfect insect* or *imago,* (see figs. 64, 65, and 66).



64. Larva.



65. Pupa.



66. Imago.

142. Tabular View of the Order of Insects.*

1. Coleoptera, or Horny-winged.	2. Hemiptera, or Half-winged.	3. Orthoptera, or Straight-winged.	4. Neuroptera, or Net-winged.	5. Lepidoptera, or Scaly-winged	6. Hymenoptera or Membrane-winged.	7. *Diptera*, or Two-winged.
1. *Pentamera* (five-parted), in which the tarsi are distinctly five-jointed. 2. *Heteromera* (differently-parted), in which the tarsi of the first two pairs of feet are five-jointed, and of the two hind pairs, four-jointed. 3. *Tetramera* (four-parted), in which all the tarsi *appear* to be four-jointed, though a very minute fifth joint exists concealed in one of the others. 4. *Trimera* (three parted), in which all the tarsi have three distinct joints; however, a very minute fourth joint is also present.	1. *Homoptera.* Cicadas, Froth-hoppers (Cercopidæ) Lantern-flies (Fulgoridæ), Plant-lice (Aphidæ), Scale Insects (Coccidæ), 2. *Heteroptera*, Land-bugs (Geocorisæ), Water-bugs, (Hydrocorisæ)	1. *Cursoria*, Cockroaches (Blattidæ), Mantidæ, Spectre-insec. (Phasmidæ). 2. *Saltatoria*, Crickets (Achetidæ), Grasshoppers (Gryllidæ), Locusts (Locustidæ). 3. *Forficulidæ*, or *Earwigs*, raised by some into a distinct order, under the name *Dermaptera* (leathery-winged).	Dragon-flies (Libellulidæ), Day-flies (Ephemeridæ) White ants (Termitidæ), Ant-lions (Myrmeleonidæ), Aphis-lions (Hemerobiidæ), May-flies (Sialidæ), Scorpion-flies (Panorpidæ), Snake-flies (Raphidiidæ), Mantis-flies (Mantispidæ), Caddice-flies (Phryganeidæ).	1. *Diurna*, or *Butterflies*, 2. *Crepuscularia*, or *Hawk-moths*, or *Sphinges*. 3. *Nocturna*, Hepialidæ, Bombycidæ, Noctuidæ, Geometridæ, Tortricidæ, Tineidæ (Clothes'-moths), Fissipennæ (Plumed moths), Strepsiptera (Twisted-winged-moths).	1. *Terebrantia*, or *Borers*. a. *Phytiphaga* (Larvæ vegetable feeders), Tenthredinidæ, or Saw-flies, Siricidæ. b. *Entomophaga* (Larvæ parasitic, feeding upon living insects), Cynipidæ, or Gall-flies,† Ichneumonidæ, Chalcididæ, Chrysididæ, or Ruby-tailed flies. 2. *Aculeata*, or *Stingers*. a. *Prædones* (of predaceous habits), Fossores, or Diggers (Sand, and wood-wasps), Formicidæ, or Ants, Vespidæ, or Wasps. b. *Mellifera*, or *Honey-collectors*, Andrenidæ, or Solitary-bees, Apidæ, or social bees. α. Bombi, or Humble-bees. β. Hive-bees.	1. *Nemocera*. Culicidæ, or Gnat-tribe, Tipulidæ, or Harry-long-legs, 2. *Notacantha*, Stratiomidæ, Beridæ, Cœnomyidæ. 3. *Tanystoma*, Tabanidæ, or Gad-fly tribe, Bombyliidæ, Anthracidæ, Asilidæ, &c. 4. *Athericera*, Syrphidæ, Muscidæ, or Fly-tribe, Œstridæ, or Bot-flies. 5. *Pupipara*, Hippoboscidæ or forest-flies, or spider-flies, Nycteribiidæ, or Bat-lice.

First Order. Coleoptera (*the Beetle tribe*).

143. The insects of the beetle tribe are characterised by the solid texture of their integuments, and by the conversion of the first pair of wings into *elytra*, or hard horny wing-cases, by which the posterior (membranous)

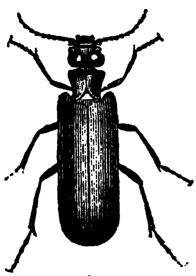
* Besides the seven orders given here, there are the three orders of *Apterous*, or *wingless* insects, viz., the *Aphaniptera*, or *Flea*-tribe, the *Anoploura*, or *Louse*-tribe, and the *Thysanoura*, which latter contains two families, viz., the *Lepismidæ*, and the *Poduridæ*, or *Spring-tails*. The second order of winged insects, that of the *Hemiptera*, is now usually divided by naturalists into two distinct orders. viz., *Homoptera*, and *Heteroptera*.

† This family corresponds however with the preceding in its general habits, and in the diet of its larvæ.

wings are completely enclosed, when the insect is at rest. The members and the buccal apparatus, more especially the *mandibles* and the *maxillæ*, are well developed. The largest and most brilliantly colored beetles are found in India and Brazil. The metamorphosis is complete in the beetle tribe. The larvæ of many of the coleopterous insects, and frequently also the latter themselves, are very destructive to vegetation; others feed on animal matters, such as the carcases and skins of animals, fur, &c., and commit occasionally considerable ravages in this way.

The most important of the section *Pentamera* are the two large tribes of the *Cicindelidæ* and *Carabidæ*, predaceous insects of most active habits, most of them carnivorous, but some also herbivorous; among the Cicindelidæ, we mention the *Sand-sparkler* (Cicindela campestris); among the *Carabidæ*, the *Goldsmith*, or *gardener beetle* (Carabus auratus), the *Sycophant* (Colosoma), and the *Bombardier beetle*. Among the *Palpicornes*, which are most of them aquatic, we notice the *Hydrophilus piceus*, a most voracious animal, which feeds upon tadpoles, upon the young frog in fish ponds, and upon small fresh-water mollusks. The type of the family *Brachelytra*, or *short-winged* beetles, is the voracious and agile *Staphylinus Erythropterus*. The *skip-jacks* (Elater), spring perpendicularly up in the air, when laid on their backs. The various species of *Buprestris* are distinguished for the brilliancy of their colors. The *death-watch* belongs to the genus *Ptinus;* many species of the sub-genus *Anobium* do much injury, in the larva state, to furniture, books, &c. Among the *Carrion beetles*, we notice the *gravedigger*, or *burying beetle* (Necrophorus), the *bacon-maggot* or *jumper* (Dermestes), and the destructive *museum beetle* (Anthrenus museorum); among the *Scarabiea*, the *Sacred beetle* of the Egyptians, the common *Dor*, the *pill-chafer* (Birrhus), or *Shard borne beetle* (Geotrupes Stercorarius), the *rose beetle* (Cetonia aurata), and the common *Cockchafer* (Melolontha vulgaris), which is most destructive to vegetation, in its larva state as well as in its insect condition. The *Stag-beetle* (Lucanus Cervus), is characterised by its large, curved, and toothed mandibles. The wingless female of the *glow-worm*, or *Lampyris*, sheds a phosphorescent light about it in summer evenings.

Among the *Heteromera* we find the *Melasoma*, or *black-bodied beetles*, among which we notice the *Blaps mortisaga*, and the *Tenebrio molitor*; the larva of the latter, known under the name of the meal-worm, is the favorite food of the nightingale. To this section belongs also the most useful of all beetles, the Spanish fly or *blistering fly* (Lytta *seu* Cantharis vesicatoria, fig. 67), which is so extensively used for vesicatories; this insect is found in great numbers on the ash and lilac, where its presence is betrayed by its unpleasant smell.



67.

In the section *Tetramera Rhyncophoræ*, we find the *weevils*, among which may be mentioned the *nut weevil* (Balaninus nucum), the *vine weevil*, and the *corn-borer* (Calandra granaria), which commits great havoc in granaries. The *diamond beetle* (Curculio imperialis), one of the most splendid of all beetles, belongs also to this tribe. Among the *Xylophagi*, or *wood-eaters*, may be mentioned the *Typographer beetle* (Bostrichus

typographus), and the *Hylurgus Piniperda*, both most destructive to trees, especially to pine-trees. The *Golden beetles*, or *Chrysomelinæ*, are brilliantly colored insects of a hemispheric or ovate form.

To the small section *Trimera* belongs the genus *Coccinella*, among which the *Lady-bird* (Coccinella septempunctata) is very useful to plants, by the destruction of hosts of Aphides which infest them.

Second Order. Hemiptera.

144. The insects of this order have the mouth adapted for suction, the tongue being elongated and channelled like a gutter, and surrounded by delicate lancet-like organs, with which the tissues of plants (and also of animals) are pierced. Most of the insects of this class subsist on vegetable juices; some, however, prey upon weaker insects; and a few species, such as the common bug, suck the juices of larger animals. To the section *Homoptera* belong the *Coccidæ*, or *scale-insects*, among which we notice the *Coccus cacti*, which furnishes the valuable cochineal; and the *Coccus lacca* of the East Indies; this latter insect pierces the bark of the Indian fig-tree, and leads thus to the exudation of a sap, which hardens in the air, and is known as a most useful article, under the name of *Lac*, or *shell-lac*. The *Aphides*, or *plant-lice*, are most destructive to plants of almost every description. Many of the *blights* so injurious to the gardener and the agriculturist consist simply of microscopic aphides. From two horn-like processes at the hind part of the bodies of the aphides, exudes a saccharine secretion which the insect drops on the leaves, and which is known as *honey-dew*. (It is not yet quite settled, however, whether the honey-dew is not the extravasated sap flowing from the wounds made by the insects in the leaves.) The *Cicada* is remarkable for the monotonous sound which it emits, and which results from the alternate tension and relaxation of an elastic membrane, placed like the skin of a drum upon the base of the abdomen. The *Aphrophora spumaria*, or *froth-hopper*, covers the willow-trees with a peculiar frothy secretion. The *Fulgoridæ* are remarkable for a curious prolongation of the forehead, which sometimes equals the rest of the body in size; it is in this prolongation that the luminous property of the *lantern-fly* of China and Guiana (Fulgora lanternaria) is said to reside. The luminousness of this insect is, however, doubted by many naturalists. The *Heteroptera* bear a close general resemblance to the Homoptera, but are distinguished by the nature of their anterior wings, which are coriaceous at their bases, and membranous only towards their points. Some of the tropical species are beautifully colored and marked. Some emit a pleasant, others, as the common *bed-bug* (Cimex lectularius), and its allies, a most disgusting odor. The common bed-bug is a wingless insect, but too well known as one of the most troublesome pests. The *Hydrometridæ*, a curious group of very long-legged insects, which may be seen on almost every pond or stream, skimming along the surface with the greatest ease and velocity, form the connecting link between the land-bugs and the true *water-bugs*. To the latter belong the *Nepidæ*, or *water scorpions*, so called from the scorpion-like form of their fore-legs.

Third Order. Orthoptera.

145. In the insects of this order the anterior wings are partially mem-

branous, and the posterior wings are folded up beneath them in a fan-like manner. The metamorphosis is incomplete in this order, the larva and pupa differing from the perfect insect only in the absence of the wings and wing-covers. To this order belong the *locusts* (Locustidæ), among which we notice the *large green locust* (Locusta viridissima), and the *migratory locusts* (Acridium migratorium), which occasionally pass from Asia into Europe in enormous swarms, and eat up every green thing; the *crickets* (Achetidæ) and the grass-hoppers (Gryllidæ), which may almost be looked upon as forming one and the same family. To this group belong our house and field-crickets, which produce a peculiar and chirruping sound by rubbing their wings against each other; and the ugly *mole-cricket* (Gryllotalpa vulgaris); the voracious *mantidæ*, or *mantis* tribe, the *walking-sticks*, and the *walking leaves* (Phyllium siccifolium); the Forficulidæ, or *earwigs;* and the Blattidæ, or *cockroaches*, nocturnal voracious insects, but too well known as a plague of our kitchens and bakehouses.

FOURTH ORDER. NEUROPTERA.

146. In the insects of this order, both the anterior and the posterior wings are membranous and transparent, and the veins or nerves, (*i. e.* the hard framework on which the membrane of the wing is extended), forms in both pairs a very beautiful minute network. Some of the Neuroptera are distinguished by the size, others by the brilliancy of their eyes. In some the metamorphosis is complete; in others there is not much difference between the larva and the perfect insect, except in the absence of wings in the former.

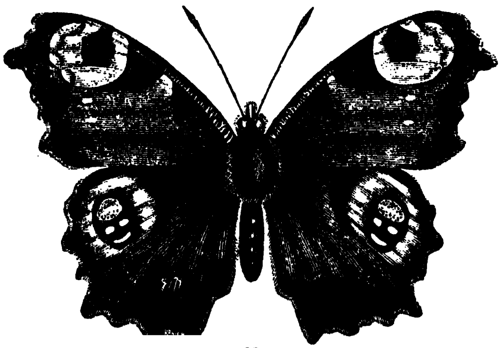
The most remarkable of the Neuroptera are the *Libellulidæ* or *Dragon-flies*, distinguished by their varied colors and their large gauze-like wings; they mostly frequent the neighbourhood of ponds and streams, where they may often be seen skimming over the surface of the water in search of flies, gnats, and other small insects, upon which they feed,—the *Myrmeleonidæ*, or *Ant-lions*, whose larvæ devour multitudes of ants, which they catch in funnel-shaped holes made in the sand,—the *Aphis-lions*, whose larvæ are extremely voracious, and destroy multitudes of Aphides,—the *Ephemeridæ* or *Day-flies*, so called from the short duration of their lives in the perfect state; these insects, after having existed for two or three years in the larva and pupa state in the water, quit that element near sunset on the fine days of summer and autumn, to undergo their final change. They are sometimes produced in such immense numbers at one time that the ground is literally covered with them, after their death; they live sometimes only a few hours in the perfect state, and never beyond the second day,—the *Termites* or *White Ants* of India, Africa, and South America, social insects which live in communities, consisting of kings and queens, soldiers and laborers; the kings and queens are perfect insects, the soldiers appear to be the pupæ, checked in their development, and the laborers the larvæ, checked in their development. The nests which they erect, and which are termed "hills," are sometimes ten or twelve feet in height. They are most destructive animals, devouring everything in their way.

FIFTH ORDER. LEPIDOPTERA.

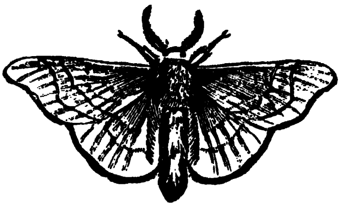
147. Lepidopterous insects are commonly ranked as *butterflies*, *moths*, and

sphinges, or *hawk-moths*. Their wings, which are mostly large, are membranous, and are covered with minute scales, having the appearance of fine dust, and which may be brushed off with the finger. The metamorphosis is complete in this order. The larvæ are called *caterpillars*, and have never more than eight pairs of legs; before they undergo the pupa metamorphosis, the larvæ generally prepare a case, or *cocoon*, as a defence for themselves, and in which they shut themselves up. The pupa is generally termed *Chrysalis*. The larvæ of many of the lepidopterous insects are notorious for the injury done by them to plants and trees; thus, the larva of the *Codling moth*, (of the family *Tortricidæ*) is one of the most destructive enemies of the apple crops of this country. Another species, the *Tortrix antiqua*, does great damage to the apricot trees; the *Tortrix gognostigma*, to the damson plum tree; the *Pyralis vitis* seu *Tortrix vitana*, to the vine; the *Noctua piniperda*, *Bombyx monacha*, *Bombyx pini*, and the *processionary caterpillar*, to forest trees, especially pines and firs; the *Tachyptera brassica*, the *Noctua brassica*, and others, to colewort and other vegetables of the kind. The *corn-moth* (Tinea granella) commits occasionally great havoc in corn. The *clothes'-moth* (Tinea sarcitella) and the *fur-moth* (Tinea pellionella), gnaw hides, wool, leather, fur, &c.

Among the most beautifully painted and marked butterflies may be mentioned the *peacock* (fig. 68), the *saturnia promethea*, the *emperor moth* (Saturnia pavonia), the *red admiral* (Tachyptera atalanta), the *painted lady*, the *convolvulus moth* (Sphinx convolvuli), the *death's-head moth* (Sphinx atropos), the *Apollo*, the *swallow-tail butterfly* (Aëronauta machaon), the *Aëronauta podaliria*, the *white-bordered mantle* (Tachyptera antiopa), the *spurge sphynx* (Sphinx euphorbii), the *sphinx ocellata*, the *Tachyptera Io*, the *purple emperor* (Tachyptera iris), the *bombyx caja*, the *noctua sponsa*, the *noctua fraxina*, the *Camberwell beauty*, the *tortoise-shell*, the *bee-bird* or *humming-bird hawk-moth* (Sphinx stellatarum).



68.

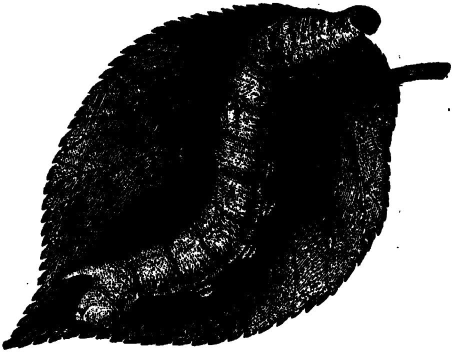


69. Silkworm Moth.

70. Chrysalis of the Silkworm.

The largest of the whole order is the *Bombyx Atlas* of China and Java, which attains a breadth of seven or eight inches across the wings.

148. The most important insect of the whole order is the *Bombyx mori*, or *silk-worm moth* (figs. 69, 70, and 71), whose larva furnishes all our silk, and indemnifies us thereby in a great measure for the ravages committed by many other members of the order. The silkworm and the mulberry tree, upon whose leaves it feeds, were first introduced into Europe from China towards the middle of the sixth century. The cultivation of the mulberry speedily spread in the Peloponnesus, which received from it its modern name of *Morea*. From Morea, the mulberry and the silkworm were imported into Sicily in 1130, and thence they spread to other parts of Italy. About 1470, they were introduced into France. Attempts have been made also, and not unsuccessfully, to cultivate the mulberry in Germany and in England. The total value of the raw silk annually produced in France is estimated at about one million pounds sterling. Silkworms remain in the larva state for about 34 days, during which time they consume an enormous quantity of mulberry leaves (the larvæ proceeding from an ounce of eggs devour from 1200 to 1500 pounds of leaves.) At the end of this time the worm spins its cocoon, of a single thread, of which the length is about 900 feet, but often exceeds 1100 feet; the weight varies, sometimes 200 cocoons weigh a pound, sometimes 400 are required to make that weight. The worms proceeding from an ounce of eggs produce usually from 70 to 80, but occasionally as much as 130 pounds of silk. It generally requires 10 pounds of cocoons to produce one pound of spun silk. From eight to twelve cocoon-threads, twisted together, give a thread of raw silk of the thickness of a hair.



71. Silkworm.

Sixth Order. Hymenoptera.

149. In the insects of this order, the four wings are membranous, as in the Neuroptera, but traversed by few veins or nerves only, and which form no close network, as they do in the latter order. The metamorphosis is complete. In the section *Ichneumonidæ*, the female is furnished with a sharp-pointed *ovipositor*, by means of which she deposits her eggs in the bodies of other insects, more particularly caterpillars, restraining thus their excessive multiplication, as the young grubs, when hatched, feed upon and destroy the animal infested by them. The *Cynipidæ* or *gall-flies* deposit their eggs in a similar manner in the leaves, buds, stalks, and young stems, and roots of various plants and trees; besides the eggs, they deposit a drop of irritating fluid, which causes the production of tumors, or *galls*, of various sizes, shapes, and colors, and the most important of which is the common *gall-nut* of commerce employed in the manufacture of ink, and in the process of dyeing black.

The *fossores*, or *Diggers*, commonly known as *Sand* and *Wood-Wasps*, are solitary in their mode of life, and so are some species of *true Wasps;* but the great majority of the latter section live together in small communities, and construct their nests with more or less artistic skill; among the *social wasps* may be mentioned the *common wasp* of this country (Vespa), and the *Hornet.* The *diggers* feed on insects, and also on the nectar of flowers; the *true Wasps* feed upon insects, meat, fruit, honey, &c. In the *formicidæ*, or *Ant tribe*, we find by the side of the winged males and females, wingless neuters, by which latter class the labors of the community are chiefly performed.

The most important of the order are the *Bees*, which store up honey in waxen cells. The *bee* tribe contains two different groups, viz., the *solitary* bees, and the *social* bees. Among the former, may be mentioned, the *mason bee*, which agglutinates bits of sand or gravel by means of a viscid saliva, and constructs with them a regular edifice; the *carpenter bee* (Xylocopa), which excavates wood with its powerful jaws; and the *upholsterer bee*, which constructs its cells out of leaves, cut into the requisite shape with truly artistic skill. Of the *social bees*, or Apidæ proper, we distinguish two groups, viz., the large *Bombi*, or *Humble bees*, and the *Hive bees*. In the latter, the social instincts and the arts of construction are exhibited in the most remarkable manner. The societies formed by them contain but a single perfect female, called the *Queen*, several hundred males, called *Drones*, and from 16,000 to 20,000 *neuters* or *workers*.

Seventh Order. Diptera.

150. To this order belong the *Culicidæ*, or *Gnat* tribe, which abound chiefly in damp places, as their larvæ are aquatic. They are but too well known as one of the greatest plagues in summer; one of the most annoying species, the *Mosquitoes*, are restricted to warm latitudes, though they make their unwelcome appearance occasionally also in colder countries during the brief but hot summer. The *bot-flies* (Œstridæ), deposit their eggs in living herbivorous animals (bullocks, horses, sheep, deer), generally in situations where the larvæ may burrow into the flesh, occasioning thus inflammatory tumors. Sometimes the eggs or larvæ, being placed upon spots within reach of the animal's tongue, are conveyed by that organ into the mouth, whence they pass into the stomach. The larvæ of one species, which infests the sheep, are found in the frontal sinuses of the skull.

The *Muscidæ*, or *fly* tribe, are in bad repute for the havoc committed by their larvæ (maggots), in meat, cheese, and other articles of food in which these insects deposit their eggs. Among them may be mentioned the *blue-bottle*, the *common fly* (Musca domestica), the *cheese-hopper fly* (Piophila casea), the *cherry-fly*, &c. The *flesh-flies*, *dung-flies*, or *carrion-flies*, are very useful in devouring the carcases of dead animals. Some species of the family *Syrphidæ* restrain the excessive multiplication of the Aphides, others of the Ants. The *Tabanidæ*, or *Gad-fly* tribe, are remarkable for the tormenting power which they possess, and which they exercise sometimes to an extent to lead to the death of the cattle attacked by them.

Seventh Class. Arachnida (*the Spider tribe.*)

151. These animals have, for the most part, a largely developed abdomen,

exceeding in size both the thorax and head, which in this class are united. To the thorax there are attached four pairs of legs, but no wings. Most of them breathe by air-sacs (*Pulmonaria*), some by tracheæ (*Trachearia*); nearly all of them have a complete circulatory apparatus. Upon the anterior part of the cephalo-thorax are placed the mouth and the eyes, which latter are always simple, and vary from two to eight, and in some of the scorpion tribe, even ten or twelve in number.

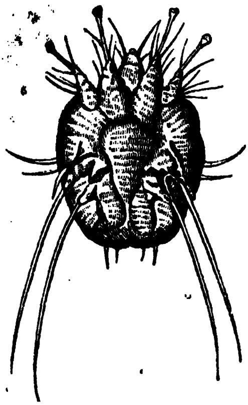
The *Pulmonaria* are divided into two sections, viz., the *Araneida* or *spiders*, which have small foot-like palpi, not terminating in pincers, and are provided with a spinning apparatus, situated in the posterior part of the abdomen, and called *spinneret*;—and the *Pedipalpi*, or *scorpions*, and their allies, which have large palpi, terminating in pincers or hooks, and are destitute of spinnerets. The *Pedipalpi* again are subdivided into two families, viz., the *Theliphonidæ*, which are simply spiders destitute of spinnerets, and furnished with long palpi; and the *scorpions proper* (Scorpionidæ), which are distinguished by their long-jointed abdomen, terminating in a venomous claw or sting, the hinder part of the abdomen is commonly called the tail. The *European scorpion* inflicts mortal wounds on small animals only, though its sting causes always a more or less serious and painful inflammation. The *scorpion* of the tropical regions, which grows from five to six inches long, is reported to inflict serious, and occasionally even fatal, stings upon larger animals, and even on man.

The *spiders* are all of them predaceous animals, feeding on insects, which they ensnare in various ways, and seize and kill with their fangs. They mostly confine themselves to sucking the juices contained in the bodies of their victims. Most of them spread nets or webs of fine silken threads, supplied by their spinnerets; some hunt their prey (*Venantes* or *hunting spiders*) either by running after it (*Cursores* or *runners*, called also *wolf-spiders*); or by leaping upon it (*Saltatores* or *leapers*); among the former we mention the *brown wolf-spider* (Dolomedes), of which the female carries her eggs about with her, enclosed in a silken cocoon or egg-case; and the *Tarentula*, celebrated for its reputed venomous powers, a reputation which rests on very slender foundations indeed, though the animal, unquestionably, like all other spiders, has a poison-gland in its mandibles. The group of the *mining-spiders*, which lurk in the cavities of rocks and stones, or burrow deeply into the ground, consists of the genus *Mygale* and its allies. These spiders are inhabitants of tropical regions and of the warmer temperate climates; they are the largest of the whole section, some of them being the size of a man's hand. Among the *Natantes* or *water-spiders*, we mention the *diving spider* (Argyroneta aquatica) which spins an oval bag, impervious to air and water, which it attaches by threads to aquatic plants, at a considerable depth below the surface of the water, the under side of this bag is open, like that of a diving bell, thus enabling the animal to pass freely in and out.

The most common of the *sedentes*, or *sedentary*, or *weaving* spiders, are the *house-spider* (Aranea domestica), and the *tortoise-shell* or *cross-spider* (Epeira diadema), the green and the gray *garden-spider*, and the very small summer or *gossamer-spider*, which covers the meadows and fields with millions of the finest threads, which are wafted about through the air by the autumnal winds.

The *Trachearia* may be divided into three families, viz., the *Pseudo-Scorpionidæ*, or *false scorpions*, among which we notice the *book-scorpion* (Chelifer), which inhabits herbaria, old books, &c., feeding upon the minute noxious insects, that prove occasionally so detrimental to collections of the kind. The *Phalangidæ*, or harvest-men, remarkable for their long and slender legs, which when detached from the body, show signs of irritability for a few moments; and the *Acaridæ*, or *mites*, very small but most noxious and noisome insects, of which some live upon decaying vegetable substances, others upon putrid animal matters, and upon various articles of food, such as meat, and old dry cheese, &c., as *e. g.* the *cheese-mite*, and the *meal-mite;* others subsist as parasites upon the skin, and in the flesh of different animals, as *e. g.* the *ticks*, which torment sheep, dogs, cows, horses, and other quadrupeds, and also fowls and pigeons (the *chicken-tick*, Acarus gallinæ); others are parasitic upon insects, more especially beetles (the Acarus coleoptratorum). One of the most noisome of the order, the *Sarcoptes scabiei*, or *Acarus of the Itch* (fig. 72), is the occasion of one of the most disgusting diseases of the skin,—the itch.

EIGHTH CLASS. VERMIFORM ANIMALS (*Annelida* and *Rotifera.*)



152. The animals of this class have generally a long, slender, and more or less cylindrical body, divided frequently into distinct segments, which, however, are only marked externally by a folding or wrinkling of the integuments. The body has an *oral* aperture at one, an *anal* aperture at the other end, and is usually furnished (in the *Annelidans*) with a series of locomotive appendages in the form of bristles, which often combine the performance of the functions of locomotion and respiration. There exists considerable variety in the arrangement of the respiratory organs, but as a general rule, the respiratory function is performed either by gills or by the setigerous appendages, or by the general surface of the body. The vermiformes have usually a distinct circulating apparatus, which, however, in the lowest order consists merely of a network of capillary vessels. Many of the annelidans are distinguished by the red color of their circulating fluid, in which they form a most remarkable exception from all other articulata. In some few of the annelidans we find a distinct contractile cavity, or respiratory heart, which serves to propel the blood through the gills; and in several a pulsation of the larger vessels is perceptible.

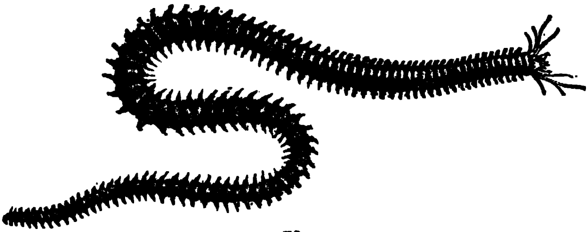
ANNELIDA.

153. Most of the annelidans are aquatic in their habits, living either in water or in moist situations. The great majority of the larger-sized of them are marine animals, as the *Nereidæ*, or *sea-centipedes* (fig. 73); the genus *Amphinome*, in which the gills have the form of branching or arborescent tufts, disposed along the whole of the body, and are often very brilliantly colored; the genus *Euphrosine*, remarkable for the large development of

their branchial tufts, and for the broad and oval form of their bodies; the *Aphrodita* or *sea mouse*, which is remarkable for the large quantity of long silky hairs of a most brilliant metallic lustre with which it is covered; the *Arenicola* or *lob-worm*, which is used by fishermen as a bait; and the *giant-worm* (Eunice gigantea) of the West Indian seas, the largest Annelide known, and which attains sometimes a length of four feet.

The annelidans of the section *Tubicolæ* reside in shells, formed in some of them of a calcareous matter, secreted from the surface of the body, in others, of grains of sand, pieces of shell, &c., cemented together. Among these we mention the *serpula*, which forms a calcareous shell that can hardly be distinguished from that of one of the mollusca, the *Vermetus*. The largest species of the *serpulæ* inhabit the tropical regions, but numerous smaller species are found on our own coasts;—and the *sabella*, which forms its shell partly of exuded calcareous matter, and partly of granules of clay or fine mud.

The order *terricolæ* contains two principal groups, viz., the *earth-worms* and the *naids*. The former belong, nearly all of them, to the genus



73.

Lumbricus, of which the common *earth-worm* (Lumbricus terrestris) is the type. The earth-worms, though feeding on the vegetables set in the soil, are much more beneficial than injurious to man, their burrowing serving as a kind of under-tillage to the land. The worms of the genus *Naïs*, of which the *Naïs proboscidea* is the type, are aquatic in their habits, living in the mud at the bottom of ponds, &c. The *naids* possess the reproductive power in a most remarkable degree; they produce buds, that separate from the parent by spontaneous division.

The order *Suctoria* contains the common *leech* and its allies. The leech used in medicine (*Hirudo officinalis*), is from two to three inches long, and about one-fifth to one-fourth of an inch thick; it is a dark-colored worm, which shows eight yellow, black, and red stripes, across the back, and is marked with yellow spots on the belly. Owing to the improvident manner in which these valuable worms have been gathered, both for domestic use and for exportation, the pools and ditches of this country have been nearly drained of them, and millions are now imported annually from abroad, to satisfy the demands of the home market. To provide for future contingencies, many artificial leech-ponds have been recently constructed. It is recommended that all leeches which have been used in bleeding should be preserved and brought to leech-ponds, lined with turf, where in the course of a few years, they may be expected to multiply to an extent to bring their price within the reach of even the poorest classes. The leech lays her eggs

in a kind of a gelatinous bag about the size of an acorn; the young leeches are quite colorless; and are unfit for medical use in the first year of their existence. The *horse-leech* is common in England and in all the British isles. It is somewhat larger than the medicinal leech, and is of no known utility.

Rotifera, or Wheel-Animalcules.

154. These minute aquatic animals* were formerly classed with the infusoria; but it has recently been ascertained that they possess a structure much more complex than that of the latter animalcules. They have usually an elongated form, and are provided at the anterior extremity with one or several rows of vibratile *cilia* usually arranged in a circular manner, and on that account termed *wheels*. The vibratile action of these cilia creates rapid currents in the surrounding fluid, by which the animalculæ whereon the rotifera feed are drawn towards their mouths. In many of the rotifera one or several red spots may be detected on the head, which Ehrenberg believes to be eyes. The body is soft and transparent, and the posterior extremity is prolonged into a tail, possessing three joints which can be drawn up within each other like the sliding tubes of a telescope. The common *wheel-animalcule* (Rotifer vulgaris), which is frequently met with in stagnant waters, may be looked upon as the type of the order.

The *Entozoa*, or *intestinal worms*, belong, strictly speaking, also to the vermiform animals; however, as many of them in their general form approximate more to the *Radiata*, we have formed a distinct class of them here, intermediate between the Articulated and the Radiated series.

Ninth Class. Mollusca.

155. The organs of *nutritive* or *vegetative* life are more highly developed in the animals of this class than they are in those of the articulated series; and some authors have on that account felt disposed to assign to the Mollusca a higher rank in the scale of the animal kingdom than to the articulated series. But, as the organs of *animal* life are so much more highly developed in the latter than in the Mollusca, there can be no reasonable hesitation to place the articulata above the Mollusca.

The digestive apparatus is always highly developed in the Mollusca; we uniformly find in them a large liver, and frequently a complete gizzard or muscular stomach; the intestinal tube is often of considerable length, and much convoluted. The blood is colorless, and circulates in a regular vascular system, of which a heart with an *auricle* and a *ventricle* forms part. The respiration of Mollusks is almost always aquatic, being carried on by the aid of gills; in some, however, as in the terrestrial *gasteropoda*, it is ærial, and the respiratory organ consists of a pulmonic cavity, presenting a complicated network of blood-vessels on its walls, and into which the air penetrates through an orifice in the outer border of the *mantle*, a spongy elastic skin, interwoven with muscular fibres, in which the soft body of the animal is enclosed in all the Mollusca. From the surface of the mantle is secreted in

* A few of the Rotifera live in moist earth.

most of the Mollusca,* a *shell* or *testa*, consisting usually of alternate layers of carbonate of lime and of membrane, but in some simply of a thin horny plate destitute of mineral matter. The shell consists either of a single piece (*univalve*), as in the snail tribe, or of two parts or valves, united by a hinge (*bivalve*), as in the oyster. The Mollusca provided with a shell are called also *testacea*, or *Conchylia*. In many of the bivalve testacea, there exists a fleshy tongue-like projection, which is termed a *foot*, and is used sometimes as a boring apparatus, sometimes as a sort of fin for swimming, sometimes to produce the *byssus*, or cord by which the animal attaches itself to rocks, &c., and sometimes to enable the animal to leap upon hard substances. In most of the univalve testacea the under side of the mantle is thickened into a fleshy disc, which is called a *sole*, and which, by its alternate contractions and expansions, serves as an instrument of progression. The nervous system is very little developed in the Mollusca, and in the lowest orders we find only a single ganglion. In the higher classes, and more especially in the highest, which comprehends the cuttle-fish and its allies, the nervous system is more complex and more highly developed. The Mollusca are usually provided with *feelers*, or *tentacula*, which are simply prolonged lips.

The great majority of the mollusca are inhabitants of the water; the largest and finest of them are found in the tropical seas. Only a few are terrestrial. The mollusca are almost all of them eatable. They live usually on vegetable substances, but some of the larger marine species live by sucking the juices of other inhabitants of the sea. They increase by eggs, which in many of them are produced in immense numbers.

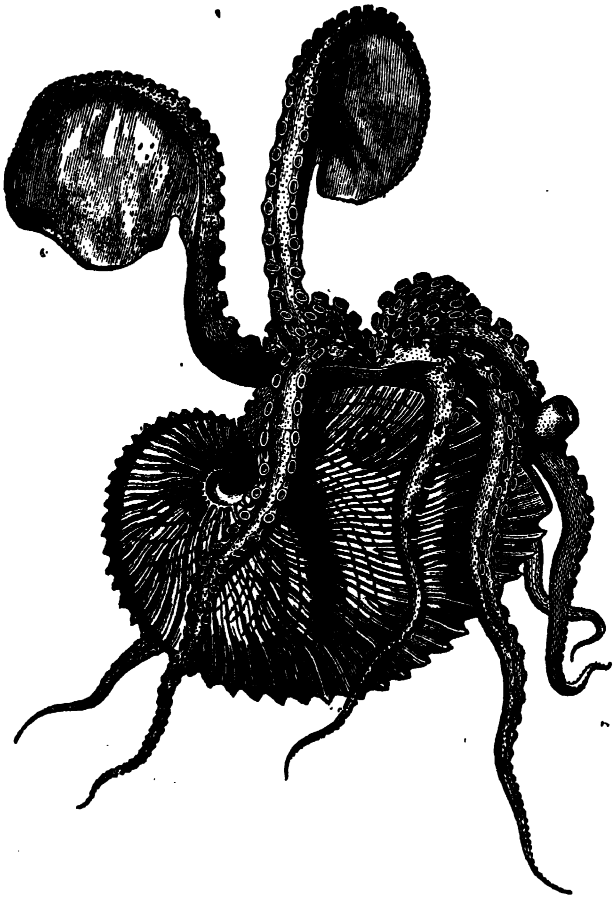
The mollusca are divided into two principal groups, viz., the *Cephalous* or *headed* mollusca, which includes all those which have a distinct head; and the *Acephalous*, or *headless* mollusca, which comprehends those in which no distinct head exists. The first group is usually subdivided into four orders, viz., the *Cephalopoda*, the *Pteropoda*, the *Gasteropoda*, and the *Heteropoda*. In the *Acephalous* mollusca we find two distinct groups, in the one of which the shell is invariably present, whilst in the other it is invariably absent; the former is therefore named *Conchiferous*, or shell-bearing, and the latter *tunicated*, the shell being replaced by a membranous or coriaceous tunic. The Conchiferous Acephala are subdivided again into the *Lamellibranchiata*, which have the gills arranged in four lamellæ, running parallel to the edges of the shell; and the *Palliobranchiata*, in which the mantle forms the respiratory surface.

156. The *Cephalopoda* are the most highly organised of the molluscous animals. They are characterised by the possession of prolonged tentacula around the head, which in some serve equally as organs of prehension and of locomotion, and are therefore sometimes called *arms*, sometimes *feet*. These arms are frequently furnished with *suckers*, by means of which the animals attach themselves so firmly to their prey, or other objects, that they may sooner be wrenched off than unfixed.

The most important animal of the order is the *cuttle-fish* (Sepia), some species of which attain a considerable size, growing sometimes to a length of six feet. This creature is found in all seas, and its appearance is that of a

* One whole order of the Mollusca (the Tunicata), have no shell, and in three other orders, the shell is frequently absent.

short-necked flask, with the mouth surrounded by eight arms. The animal is provided with a very singular secreting organ, which produces an abundance of a black liquor, commonly termed its *ink*, and which is used in painting. The only rudiment of a shell in the cuttle-fish is a straight, flat, broad, and firm body, the so-called *pounce-bone*.

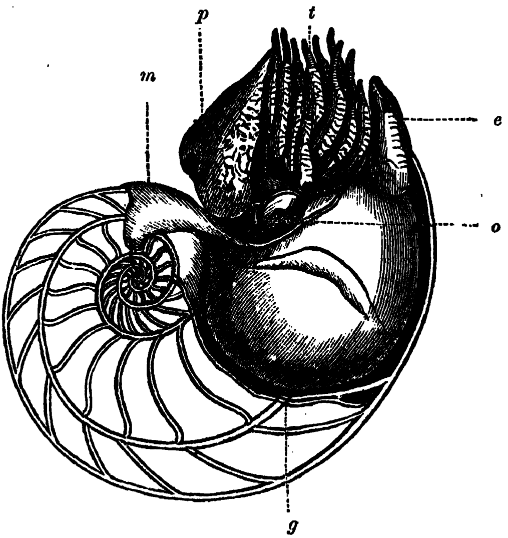


74.

The smaller *sepias*, which often appear in enormous shoals, are much relished by the cod and the Cetacea. The *Octopus* or *Poulp* (Octopus vulgaris,) is common on the southern coasts of Europe, and is occasionally met with on our own shores. This animal is the *Polypus* of ancient naturalists. The largest species of which we have any authentic account, do not measure above four feet between the ends of the arms; but a gigantic species is said to exist in the Indian Archipelago, which is asserted

to measure twelve feet over the centre of the body, with arms 54 feet long. Making allowance for a great deal of exaggeration in the accounts given of these marvellous monsters, still there is no valid reason to doubt the existence in the open seas of Octopi of much larger size than any that we are as yet familiarly acquainted with; and it is probably one of these animals which has given rise to the tales of the fabulous *Kraken* of the Norwegian seas. A most interesting species of the Octopod group is the *Argonauta* (fig. 74), commonly called *paper nautilus*, from the whiteness and delicacy of its shell.

The only existing representative of the suborder *Tetrabranchiata*, or *four-gilled* Cephalopoda, is the *pearly nautilus* (Nautilus pompilius, fig. 75), of which the beautifully convoluted nacreous shell is made into drinking-cups.



75.

[Pearly Nautilus, with the shell laid open; *t*, tentacula; *e*, funnel; *p*, foot; *m*, portion of mantle; *o*, eye; *g*, siphon.]

The stratified rocks (Mineralogy, § 114) contain many fossil remains of Cephalopoda, among which may be noticed the *ammonites*, the *belemnites*, the *turrilites*, the *baculites*, the *orthoceratites*, and the *crioceratites*.

The *Pteropoda*, so called from the fin or wing-like expansions of the mantle on each side of the neck, which serve to propel them rapidly through the water, are mostly animals of very small size, but which often associate together in enormous shoals. Among them we notice the *Clio*, or *whales' food*, which is among the chief articles on which the whale is supported.

157. The *gasteropoda* or *snail* tribe form a most extensive and important group. Most of the animals belonging to it, live in a univalve shell, which is usually cone-shaped and rolled into a spiral; some species, however, are perfectly *naked* (destitute of a testaceous covering), as the *slug*, for example.

The *gasteropoda* move about by means of a fleshy disc, or foot, placed under the abdomen. They are generally formed for crawling, but some are rather adapted for swimming. Most of them carry tentacula in front. Those which inhabit the tropical seas are distinguished by the size and the beautiful coloring and lustre of their shells, which are used for many ornamental purposes.

We can here notice only a few of the most important members of this extensive order, such as the *Doris* (Doris cornuta); the *Aplysia* or *sea-hare* (Aplysia depilans), which discharges in its defence a deep purple liquid, said to possess acrid and depilatory properties; the *nipple-shell;* the *Bulla lignaria* and *Bulla ampulla;* the *Bursatella* of the Indian seas; the *Chitons* and *Limpets.* Most of these live on sea-weed. Among the *naked snails,* or *slugs* (Limacinæ), we mention the red and brown *common slug* (Limax rufus), and the *salad slug,* or *field slug* (L. Agrestis); among the *testaceous* or *true snails* (Helicinæ), which possess convoluted shells, we notice the *common garden-snail* of this country (Helix hortensis), the *edible snail* of France and Italy (H. pomatia); among the aquatic snails, the *Planorbis,* the *Paludina,* and the *Lymnæa stagnalis,* which inhabit ponds, shallow streams, and the banks of rivers, or also occasionally the sea shore.

One of the most beautiful marine snails is the *wentletrap* (Scalaria preciosa), for which high prices were formerly given by shell-collectors. Of the genus *turbo,* to which the common periwinkle belongs, there is a species in Holland which is salted and used as food.

The following also deserve to be noticed: the *Cones;* the *Volutes;* the *Cypræa* or *cowries,* which are remarkable for the *porcelainous* texture and brilliant colors of the shells, and the high polish of which they are susceptible; the large cowrie or *tiger shell* (Cypræa tigris), is frequently made into snuff-boxes, &c.; the small cowrie or *money cowrie* (Cypræa moneta), is the current coin of the natives of Siam, Bengal, and many parts of Africa. Nearly allied to the cones and cowries, are the ovula, oliva, and many other genera. Of the genus *Buccinum,* we notice the *Buccinum undatum,* or *whelk* of our own shores, and the *Buccinum harpa.* Nearly allied to the genus Buccinum is the *Cassis* or *helmet-shell,* some species of which, as the Cassis rufa, for instance, are beautifully sculptured by Italian artists, in imitation of *antique cameos.* From the animals of the genus *Purpura,* the celebrated Roman purple dye was obtained; a small quantity of this may be obtained from the *Purpura lapillus* of our own coasts. The family *Muricidæ* and its allies are distinguished by the great length of the siphon, and (in many instances) the remarkable prolongation of the siphon canal. The *Pteroceras scorpio* is remarkable for the long finger-like processes with which the greatly-extended lip is beset.

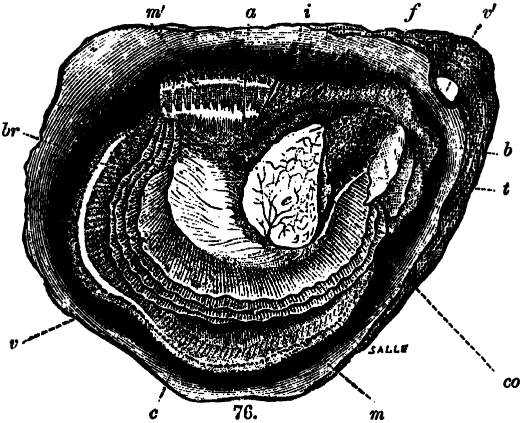
158. The most important order of the *Acephalous* section of Mollusca is that of the *Lamellibranchiate Conchifera.* All the animals belonging to this group have *bivalve shells,* jointed by a hinge, and shutting and opening by means of the so-called *adductor* muscle. They are aquatic animals, distributed over the whole globe, and principally frequenting the shores or shallows. Among the most important of them we notice the *Teredo navalis* or *timber-borer,* one of the most formidable destroyers of the works of man, and which attacks the bottoms of ships, and the piles of bridges, piers, and harbors, perforating the timber in every direction; the *Pholades* (Pholas

dactylus and some other species), which form their cells mostly in rocks, which they excavate by means of the hard, siliceous, rasp-like surface of their shells; they are much prized as food, and possess the remarkable property of phosphorescence; the *Aspergillum;* the *Solen* or *razor-shell;* the edible *cockles* or *Cardia* and their allies, the *Donax, Mactra, Lucina, Tellina gari,* from which latter a very palatable sauce is prepared in India, &c.

Among the fresh-water Conchifera we notice the *Anatina*, the *painter's gaper* (Mya pictorum), of which the shells are used for keeping painters' colors; and the *fresh-water pearl-shell* (Mya margaritifera), which abounds in most rivers of the North, and yields occasionally very valuable pearls.

The following are confined exclusively to the sea: the *arca*, the *giant clamp-shell*, or *tridacne* (Chama gigas), which is found in the East Indian and Australian seas, and is the largest of the whole class, often attaining a circumference of from six to eight feet, and a weight of 200 lbs. and more; the edible *mytilus*, with a triangular ham-shaped dark violet-colored shell. A bunch or tuft of silky hair, called *Byssus*, about a foot long, proceeds from the base of the foot of this mussel. In the *pinna*, or wing-shell, this byssus is very long and silky, and the inhabitants of Sicily and Calabria manufacture it into a stuff remarkable for its suppleness and warmth. There is also frequently found in the pinna a small crab, called on this account *pinna-warder*. The genuine *pearl-oyster*, or *pearl-mussel*, which produces the precious pearl, and the mother-of-pearl, is caught by pearl-fishers or divers on the shores of Ceylon, the Persian Gulf, and other parts of the borders of the Indian Ocean, and also in the Gulf of Panama, and on the eastern shore of California.

But the most important of the Conchiferous molluscs is unquestionably the well-known *oyster* (Ostrea edulis, fig. 76), of which several species are



76.

[Anatomy of the Oyster: *v*, one of the valves of the shell; *v'*, its hinge; *m*, one of the lobes of the mantle; *m'*, a portion of the other lobe folded back; *c*, adductor muscle; *br*, gills; *b*, mouth; *t*, tentacula, or prolonged lips; *f*, liver; *i*, intestine; *a*, anus; *co*, heart.]

found on all the shores of Northern Europe. The dredging, storing, exporta-

tion, and sale of oysters, gives occupation to thousands of families. A single oyster is said to produce as many as 1,500,000, or even 2,000,000 eggs. Allied to the oysters are the *pectens*, or *clams*, among which we notice the *pecten maximus*, or *pilgrim's scallop shell.*

159. The *Palliobranchiata* are also called *Brachiopoda*, or *arm-footed*, on account of the presence of two long spiral arms, one on each side of the mouth. The number of living species is very small, but the order includes a very large proportion of the Bivalve mollusks of the older rocks. The greater part of the existing *Brachiopoda* belong to the genus *Terebratula*, which, besides about 40 known living species, includes several hundred fossil species.

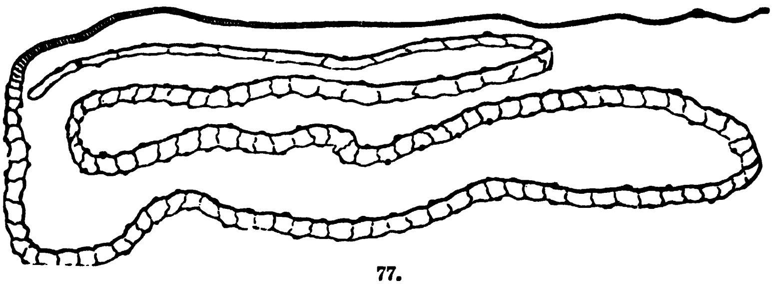
160. The mollusca of the class *Tunicata* are altogether destitute of a calcareous shell, but they are enveloped in a firm elastic *tunic*. The peculiar and distinctive character of this group is the tendency to the association, or union, of a number of independent individuals to form a species of compound animal. This tendency to aggregation exhibits itself in various ways: sometimes the individuals adhere simply externally; sometimes there are a number of individuals, destitute of their own external coats, enclosed within a common envelope; and, in some cases, several individuals share in a common circulatory system, the vessels passing along a stem, with which all the component individuals are connected by short footstalks. We notice among the *Tunicata*, the isolated and aggregated *Ascidiæ*, and the isolated and aggregated *Salpæ*; one of the most brilliant combinations of the latter is that which forms the *Pyrosoma*, so remarkable for the sparkling phosphoric lights emitted by it; the most singular phenomenon connected with the phosphorescence of the Pyrosoma mass is, the rapid change of the color of the light from intense red successively to crimson, orange, greenish, azure blue, and finally, when the mass appears to be in a state of absolute repose, to opaline yellow.

TENTH CLASS. ENTOZOA *(Intestinal Worms).*

161. As their name implies, the animals of this class pass their life in the bodies of other animals, upon the juices of which they subsist; most of them reside in the cavities of the body which they infest, but some burrow also in the areolar tissue, and in the flesh of man and other animals. There are about 1500 species known of them. They are divided into two sections, viz., the *Sterelmintha*, which approximate to the *Annelida*, having a distinct intestinal tube with oral and anal orifices, and presenting also traces of a muscular and nervous system; and the *Cœlelmintha*, which are destitute even of a distinct alimentary canal.

Among the *Sterelmintha*, we notice the *Linguatula tænioides*, a worm which infests the frontal sinuses of the horse and dog; the *round-worm* (Ascaris lumbricoides), and the *thread-worm* (Ascaris vermicularis), which both infest the intestines of man, and also of the lower animals; the *trichocephalus*, also an inhabitant of the human intestines; the *guinea-worm* or *Filaria*, which burrows in the flesh of man and other animals in warm climates, and grows to the length of several yards; the *Strongilus*, which is found in the kidneys of man, horses, &c.; the *Strongilus filaria*, which takes up its abode in the trachea of sheep, where it excites violent coughing.

Among the *Cœlelmintha* we have the well-known *tape-worm* (Tænia solium, fig. 77), which occasionally attains a length of ten feet, and is found



77.

more particularly among the Western nations of Europe; and the *Botriocephalus*, which attains a length of twenty feet, and is confined more to the inhabitants of the East of Europe.

In the suborder *Cystiformes*—worms having the body dilated into a large bag filled with fluid—we find the *Cysticercus cellulosæ*, which infests the areolar tissue, and the substance of the various membranes; this parasite is not uncommon in man, but it is chiefly found in the pig. Another species of this suborder is the cause of the so-called *staggers*, a disease to which sheep are very liable.

RADIATA.

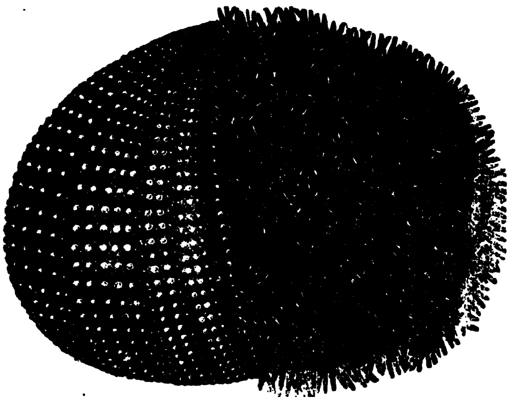
The Radiated subdivision of the animal kingdom comprises all those animals in which there is a regular disposition of similar parts around a common centre.

Eleventh Class. Echinodermata.

162. The *Echinodermata* are characterised chiefly by their hard integument, generally beset with spines, or prickles, and from which the name of the class is derived. In some of them, as in the *Cidaris*, for example, the spines perform the locomotive function, acting as so many legs; in others, as in many of the *Echinida*, the locomotive function is discharged by organs of a very different character, viz., by a number of very delicate membranous tubes, each of them furnished with a sucker at its extremity, and capable of being projected to a considerable length from the openings in the so-called *ambulacral* plates of the shell in which they are placed. In many species, this locomotive apparatus affords also the principal instrument of the prehension of food. In the common *Asterias* or *star-fish*, these tubular suckers project in great numbers from the under side of the arms. Besides these tubular feet we find, in certain species of the *star-fish* and of the *Echinus*, another set of prehensile organs, consisting of a series of stems, disposed over the greater part of the surface of the body, and bearing each at the summit a sort of forceps of calcareous matter.

The *Echinodermata* are divided into three orders, viz., the *Echinida*, the *Stellerida*, and the *Fistulida*.

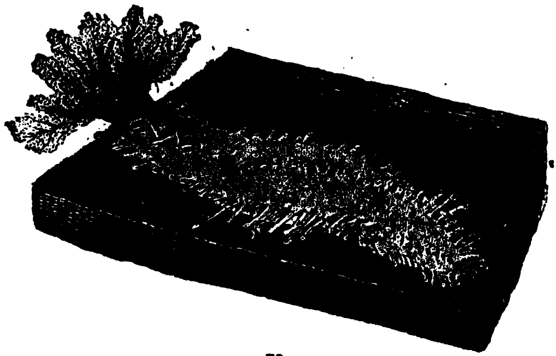
In the *Echinida*, the form of the body is globular, semi-spherical, or cordate. The intestinal canal forms a long tube, with two orifices, of which the *oral* is usually on the under, the *anal* on the upper side of the animal; this tube makes generally two turns within the shell. Small Crustacea and Mollusca constitute the chief food of the animals of this order; some of the larger species are edible. The best known of the order are the *Echinus* or *sea-urchin* (fig. 78), and the *Cidaris imperialis*.



78.

Among the *Stellerida* we notice the *Asterias* or *star-fish*, which present the form of flattened five-rayed stars; the *Ophiuræ*, in which the arms are of a round tapering form, like a serpent's tail; and the *Euryale* (Euryale caput medusæ), in which the arms ramify minutely, dividing and subdividing again into branches; and the interesting family *Crinoidea*, or *lily-stars*, or *sea-lilies*, which are attached, during a portion or the whole of their lives, by a footstalk, or peduncle, to some solid body.

The order *Fistulida* consists of the *Holothuriæ* and their allies; among which we notice the *Sipunculus*, which is used as an article of food in China and Japan; and the *sea-cucumber*, or *Trepang*, or *Bêche de mer* (Holothuria edulis), a most important article of food with the Chinese.



79.

Skeletons of *Crinoidea* are found in abundance in the limestones of the transition series, and also in the carboniferous series; fossil remains of the Stellerida and Echinida are met with in almost all marine strata, but more particularly in the Chalk and Oolite.

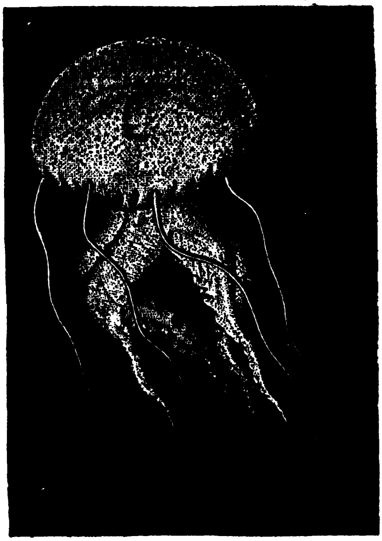
Twelfth Class. Acalephæ (*Sea-Nettles* or *Stang-Fishes.*)

163. The *Acalephæ* (so called from the stinging power which nearly all of them possess, and which appears due to a peculiar secretion from the acrid

surface), are characterised chiefly by the extreme softness of their tissues, which has also led to their being sometimes called *jelly-fish* or *sea-blubber*. In the greater number of them, there is no hard support whatever, and the body of the animal, when taken out of the water, melts away, and loses its form completely; in a few species, however, there is a very thin cartilaginous plate which retains its form when dry. So little solid matter do these animals contain, that a *Medusa*, weighing several pounds when alive, is reduced almost to as many grains when dried. Some of the Acalephæ, when floating in their native element, present to the eye an umbrella-shaped disc, from beneath which hang down a number of tentacula or arms (usually four or a multiple of that number, which would seem almost constantly to govern the distribution of the organs in these animals). Some species of Acalephæ have no regular mouth; the food being taken in by a number of suckers, having minute orifices at their extremities. Notwithstanding the extreme delicacy of their structure, they feed upon small Crustacea, Mollusca, and even fishes. Many species are phosphorescent, and, in the warmer latitudes, they occasionally charm the eye of the voyager at night with a brilliant display of luminosity.

We notice among them the *Medusa*, the *Pelagia* (fig. 80), the *Cydippe* (formerly called Beroe), the *Cestum Veneris* or *girdle of Venus*, the *Berenice*, the *Rhizostoma*; and among the so-called *Hydrostatic* Acalephæ, the *Physalus* or *Portuguese man-of-war*.

The Acalephæ are of no known utility to man, but they may afford subsistence to marine animals.

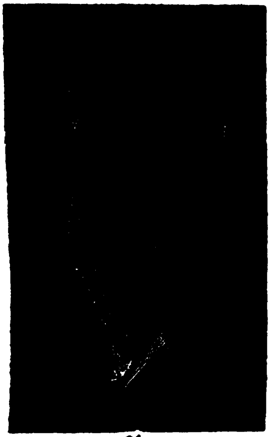


80.

Thirteenth Class. Polypifera.

164. The *Polypifera* (the *Zoophytes* of the older botanists), present most of them a plant-like aspect. In general they have only one orifice, the *mouth*, round which are arranged a certain number (6, 8, 10, 12, and more) of *tentacula*, or arms, diverging from each other like the spokes of a wheel. They increase mostly by *buds* developed from the external surface of the body; the young polype remaining connected for a time with the parent, and not unfrequently producing buds from itself, before its separation. The propagation of the Polypifera is effected also by *ova*. Some of them deposit a hard skeleton, either massive and stony *(lithophytes)*, or horny and flexible *(keratophytes)*; others, the so-called *naked* polypes, as the *Hydra* and the *Actinia*, are destitute of any hard covering.

The polypifera are divided into four orders, viz., 1, The *Hydroida*, or *fresh-water polypes*, among which we notice the *green polypi* (Hydra viridis, fig. 81), and the *brown polype* (Hydra fusca). The Hydra possesses in a most remarkable degree the faculty of reproducing the whole structure from separate portions of it; thus, the animal may be divided transversely into segments, or longitudinally into strips, and every segment or strip will speedily become a new animal; the body may also be turned inside out, apparently without the least injury to the animal. 2, The *Helianthoida*, a group of which the common *sea-anemone*, or *actinia* (fig. 82), may be regarded as the type. In this order of polypes the mouth is fringed with numerous short fleshy arms, arranged in several circular rows; an expanded fleshy disc, of sufficient size to take a firm attachment to the rock upon which the animal is fixed, forms the whole base of the body. In its contracted state the animal presents an almost hemispherical form; but, when fully expanded, the body may be compared in shape to a small flowerpot. The Actiniæ prey upon small crustacea, fish, &c., and are, in their turn, preyed upon by the larger species of these tribes, and more particularly by the whale. They are also eaten by man. Besides the *Actiniæ*, this order contains several other genera, of which some are *naked*; whilst others, as the *Caryophyllia*, *Dendrophyllia*, *Madrepores*, form a hard calcareous skeleton, or stony cell, in the bottom of which are to be seen a number of thin vertical plates, or *lamellæ*, radiating from the centre towards the circumference. It is principally by the animals of this group that the formation of coral reefs and islands is effected.



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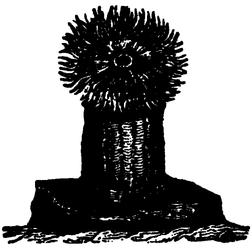

82.

These coral structures are found more particularly in the Polynesian Archipelago, and in the Indian Ocean. 3. *Asteroida*, or *Alcyonian* polypes, so termed from one of the principal genera constituting the order. In many of these, the solid framework, or *polypidom*, resembles *sponge** so closely that it is difficult to distinguish between the two. Among the Alcyonian polypes may be noticed the *Alcyonium;* the *Pennatula*, or *sea-pen;* the *red coral;* the *Gorgonia*, or *sea-fan;* the *Antipathes*, or *black coral;* the *Isis Hippuris;* and the *Tubipora musica* or *organ-pipe coral*. And, 4, The *Ciliobrachiata;* in the polypes belonging to this order the tentacula are set on both sides with cilia, hence the name of the order. Among them we notice the *Plumatella*, and the *Flustra* or *sea-mat*.

* The real *sponges* and their allies constitute the class *Porifera*, which occupies the lowest rank in the animal creation; the beings which it contains, exhibiting so few indications of any but *organic* or *vegetative* life, that it may almost be considered still doubtful whether their proper position is not in the vegetable kingdom.

Fossil corals are found petrified in immense quantities, even in the oldest formations (Miner. § 114).

FOURTEENTH CLASS. POLYGASTRIA (*Infusorial animalcules*).

165. Decaying vegetable or animal substances, such as the leaves of trees, grass, a piece of flesh, &c., affused with water and exposed to air and warmth, will speedily, upon microscopic examination, be found peopled with numbers of most active minute creatures of the most varied forms. These animalcules are found also in the stagnant pools around our cities; in the waters of rivers, harbors, and lakes, and even in the ocean.

In reference to the origin of these animalcules, the view was long entertained that they were generated spontaneously, that the decaying vegetable and animal substances were decomposed and resolved into these simple beings. More accurate experiments have shown, however, that the infusoria are produced from ova or germs which are probably carried about in the dried-up state, in the form of minute particles of dust,* ready to develop themselves in any spot which may afford them the requisite moisture and nutriment. In this respect they resemble the microscopic fungi, whose germs are diffused in the same way. When once they have obtained the means of development, they multiply with incredible celerity. If the decaying vegetable or animal substances be carefully excluded from contact with the air, or if the air be heated before it is admitted to them, no *infusoria* will appear. They are rarely developed on mountains of a certain height, where the atmosphere is free from foreign bodies.

These minute creatures feed partly on the decaying vegetable and animal substances in which they are developed, and partly they devour each other with great voracity. Some species are furnished with *cilia* disposed around the mouth, towards which they produce a vortex of fluid that brings a supply of alimentary particles.

Though these animalcules be so exceedingly minute, yet the forms exhibited by them are extremely various, and some of them present also considerable variety in the forms assumed by the same individual under different circumstances. In many species, the soft body is enclosed in a firm integument, strengthened by a deposit of siliceous matter; these envelopes, which are often preserved after the death of the animals, are termed the *shields*, and the animalcules encased in them are called *loricated* infusoria. The remarkable discovery has been made that large distinct beds of former formations are entirely made up of the accumulated remains of these animalcules (Comp. Mineralogy, § 145). In some species, the shield contains also sesqui-oxide of iron.

Among the infusoria we notice the *Monads*, the *Volvox*, the *Navicula*, the *Vorticella*, the *Stentor* or *Trumpet vorticella*, the *Vibrio*, the *Paramecium aurelia*, the *Euglena*, and the *Cyclidium*.

* That the presence of millions of such ova in the air should not be detected, will appear very natural indeed, if we reflect that the animalcules are only 1-1500 to 1-2000th part of a line in diameter, and that the ova are a thousand times smaller.

INDEX.

[Birth-place of Newton.]

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